VOL. 1. JUNE, 1915. PART 4.

JOURNAL

OF

THE INSTITUTION

OF

PETROLEUM TECHNOLOGISTS

AND

RECORD OF TRANSACTIONS.

FOUNDED 1913—INCORPORATED 1914.

PUBLISHED BY
THE INSTITUTION OF PETROLEUM TECHNOLOGISTS
17, Bloomsbury Street, W.C.
AND PRINTED BY
GEOUTHER & GOODMAN,
14a, Finsbury Street, London, E.C.

PRICE 5s.

All rights of Publication or Translation are reserved.

MODERN REFINERY WORK.

COMPLETE PLANTS - AND MACHINERY -

SUPPLIED FOR

Acid Pumping by New Method.
Asphalt Distilling.
Benzine, Kerosine and Lubricating Oil Washing.
Benzol Recovery.
Continuous Benzine Rectification.
Continuous Crude Oil Distillation.
Continuous Residue Distillation.
Continuous Vacuum Oil Distillation for Lubricating & Vacuum Oils.
Continuous Petrol Washing.
Cracking and Coking Distilling.
Debenzination of Crude Oil.
Lignite Distillation.
Paraffin Extraction and Refining.
Petrol Rectifying.
Pumping Installations.
Shale Distillation.
Sulphuric Acid Recovery.
Uncondensable Gas Plant and Benzine Enrichment.
Vacuum Continuous Lubricating Oil Distillation.

Stills, Retorts, Superheaters, and Houtejes for all Purposes.

NEW PLANTS DESIGNED TO SUIT SPECIAL REQUIREMENTS.

WRITE FOR PAMPHLET ON MINERAL OIL DISTILLATION.

W. J. FRASER & CO., LTD.,

ENGINEERING WORKS,

DAGENHAM, ROMFORD, ESSEX.

Telegrams:
"FRASER, DAGENHAM"

Telephone:
[illegible] ROMFORD (3 lines).

LIST OF THE OFFICERS

OF

The Institution of Petroleum Technologists, 1914—1915.

President:

Sir Boverton Redwood, Bart., D.Sc., F.R.S.E.

Vice-Presidents:

The Rt. Hon. Lord Cowdray of Midhurst.
Sir Thomas H. Holland, K.C.I.E., D.Sc., F.R.S.

Members of Council:

Alfred C. Adams.
Herbert Allen.
Sir Robert Balfour, Bart., M.P.
R. W. Barnett, M.A.
George T. Beilby, LL.D., F.R.S.
Edwin R. Blundstone, B.A., F.C.S.
Professor John Cadman, D.Sc., M.Inst.C.E.
John T. Cargill.
Major A. Cooper-Key, C.B.
E. H. Cunningham Craig, B.A., F.G.S.
Arthur W. Eastlake, M.Inst.M.E., A.M.I.Mech.E.
C. Greenway.
Professor Vivian B. Lewes, F.C.S., F.I.C.
T. C. Palmer, Assoc.M.Inst.C.E.
F. Mollwo Perkin, Ph.D., F.I.C., F.C.S.
Robert Redwood, F.C.S.

Honorary Treasurer:

Sir William Plender.

Honorary Solicitor:

Sir Frank Crisp, Bart.

Honorary Auditors:

Messrs. Price, Waterhouse & Co.

Bankers:

The London County and Westminster Bank, Limited,
21, Lombard Street, London, E.C.

Hon. Editor and Librarian:

W. H. Dalton, F.G.S., F.C.S.

Hon. Secretary:

Arthur W. Eastlake, M.Inst.M.E., A.M.I.Mech.E.
Offices, 17, Gracechurch Street, London, E.C.

COMMITTEES.

ELECTION, FINANCE AND PUBLICATION.

Members of the Election Committee.

GEORGE T. BEILBY, LL.D., F.R.S.
EDWIN R. BLUNDSTONE, B.A., F.C.S.
Professor JOHN CADMAN, D.Sc., M.Inst.C.E.
ARTHUR W. EASTLAKE, M.Inst.M.E., A.M.I.Mech.E.
Sir THOMAS H. HOLLAND, K.C.I.E., D.Sc., F.R.S.
T. C. PALMER, Assoc.M.Inst.C.E.
Sir BOVERTON REDWOOD, Bart., D.Sc., F.R.S.E. (*ex officio*).

Members of the Finance Committee.

ALFRED C. ADAMS (*Chairman*).
ARTHUR W. EASTLAKE, M.Inst.M.E., A.M.I.Mech.E.
T. C. PALMER, Assoc.M.Inst.C.E.
ROBERT REDWOOD, F.C.S.
Sir BOVERTON REDWOOD, Bart., D.Sc., F.R.S.E. (*ex officio*)

Members of the Publication Committee.

GEORGE T. BEILBY, LL.D., F.R.S.
EDWIN R. BLUNDSTONE, B.A., F.C.S.
Professor JOHN CADMAN, D.Sc., M.Inst.C.E.
Sir THOMAS H. HOLLAND, K.C.I.E., D Sc., F.R.S.
Professor VIVIAN B. LEWES, F.C.S., F.I.C.
F. MOLLWO PERKIN, Ph.D., F.I.C., F.C.S.
Sir BOVERTON REDWOOD, Bart., D.Sc., F.R.S.E. (*ex officio*).

CONTENTS.

	PAGE.
Council and Officers	i
Committees	ii
General Notices:—	
Copyright	iv
Issue of Journal	iv
Changes of Address	iv
To Authors of Papers	iv
The Library	v
Advertisements in the Journal	xiv
List of Advertisers	xiv
Personal Notes of Members and Special Notices	xiv
Newly-elected Members	xviii
Proposed Dinner and Lunch Club	xviii
Editorial:—Drilling Logs	191
Fifth General Meeting, 18th March, 1915.	
Paper: The Internal-Combustion Engine on the Oil Field, by F. G. Rappoport, Assoc. M. Inst. C.E., M.I.Mech.E.	195
Discussion: by the PRESIDENT, and Messrs. W. Calder, E. W. Petter, H. Wyatt, J. Wells, and M. A. Ockenden	214
Sixth General Meeting, 30th April, 1915.	
Paper: Oil-well Engineering, by William Calder, M.Inst.M.E.	228
Discussion: by the PRESIDENT, and Messrs. J. Wells, F. G. Rappoport, M. A. Ockenden, and C. Temple Orme ...	262
Seventh General Meeting, 28th May, 1915.	
Paper: The Evolution of the Oil Tank-Ship, by Herbert Barringer, M. Inst. C.E., M. I. Mech. E., M.I.N.A....	280
Discussion: by the PRESIDENT, Col. Saxton White, Messrs. A. J. Dudgeon and J. W. Isherwood ...	314

NOTICES.

The Institution as a body is not responsible for the statements or opinions expressed in any of its publications.

Copyright. The entire contents of the Journal are covered by general copyright, and official permission is necessary for reprinting long abstracts; but editors may use not more than three pages of any paper, provided that credit is given as reproduced from the Journal of The Institution of Petroleum Technologists.

Issue of Journal. Notice of the publication of each part of the Journal is contained in the first subsequent circular issued to the members, and in case of non-receipt, immediate intimation should be given to the Secretary. Duplicate copies of any parts can only be supplied to members on payment of 5s. each, plus postage; but cannot even then be had if the parts have been bound into volumes.

The Memorandum and Articles of Association, and the By-laws and Regulations of the Institution were published in the first issue of the Journal, and will in future be published in the first issue of every session.

Changes of Address. It is particularly requested that members notify the Secretary immediately, of any change of address; and members are also requested to advise the Parcel-Post Department as well as the Letter Office, of any temporary change of address, as, unless this is done, parcel-post packets will not be re-addressed; but will be returned to the offices of the Institution in London, thus incurring further expense for postage.

To Authors of Papers. Papers should be written in the third person, and the copy should be carefully corrected by the author before it is presented.

All drawings, diagrams or other illustrations should be sent in a fit state for direct photographic reproduction.

All quotations, technical terms, and localisms should be indicated by means of inverted commas.

Foreign weights, measures, and costs should be given whenever possible; and also their English equivalents.

It is suggested that authors append as complete a bibliography of the subject treated as may be possible.

All papers and notes submitted to the Institution are supposed to be original communications unless distinctly stated to be otherwise, in which case exact reference to the previous publication should be given.

The Library. In the extensive additions to our Library during the past three months, as catalogued below, is included a most generous gift from Sir Thomas B. Bowring, of a series of standard works of reference in chemistry, geology, and technology, bringing our collection in these respects as nearly up to date as the constant advance of science permits. The Institution is deeply indebted to the donor for this handsome assistance.

We shall be particularly thankful for gifts of monographs on limited branches of our wide range of subjects, and for separate copies of papers contributed to other Institutions or Journals.

Books Received since the Issue of no. 3.

Best, W. N. The Science of Burning Liquid Fuel. A Practical Book for Practical Men. 8vo, *London*, 1913.
From Sir T. B. Bowring.

Bosworth, Dr. T. O. Outlines of Oilfield Geology. *Geol. Mag.*, dec. 5, vol. ix, pp. 16–23, 53–59. [1912].

—— The Birth of an Island near the Coast of Trinidad. *Ibid.*, pp. 159–163. [1912]. *From the Author.*

Brame, J. S. S. Fuel: Solid, Liquid and Gaseous. 8vo, *London*, 1914. *From Sir T. B. Bowring.*

Butler, E. Oil Fuel: its Supply, Composition and Application. Ed. iii. 8vo, *London*, 1914. *From Sir T. B. Bowring.*

Canada. Department of the Interior.

Haanel, E. Report on Copper Belt and Coal Lands near White Horse, Y.T. and on the Mining Conditions of the Klondike, Y.T. Appendix to the Report of the Superintendent of Mines, 1902. *Ann. Rep.*, pt. vi.

—— On the Location and Examination of Magnetic Ore Deposits by Magnetometric Measurements. (*Ann. Mg. Canad. Min. Inst.*, 1903). *Ottawa*, 1904. [= no. 5 of *Reports of the Mines Branch, Canada Dep. Mines*].
From the Secretary, Mines Branch.

CANADA. DEPARTMENT OF MINES, MINES BRANCH.

ANREP, A. Investigation of the Peat Bogs and Peat Industry of Canada 1910–11, *Report*, no. 151 (*Bulletin*, no. 8), 1912.

—— [*Idem*], 1911–12. *Ibid.*, no. 266 (*Bull.* no. 9), 1914.

CARTWRIGHT, C. T. The Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and other Metals in Canada During the Calendar Year 1913. *Ibid.*, no. 317, 1914.

CIRKEL, F. Report on the Chrome Iron Ore Deposits in the Eastern Townships, Province of Quebec. *Ibid.*, no. 29, 1909.

—— Chrysolite-Asbestos: its Occurrence, Exploitation, Milling and Uses. *Ibid.*, no. 69 (Ed. 2), 1910.

COLE, L. H. Gypsum in Canada: its Occurrence, Exploitation, and Technology. *Ibid.*, no. 245, 1913.

COLEMAN, A. P. The Nickel Industry: with special reference to the Sudbury Region, Ontario. *Ibid.*, no. 170, 1913.

DESBOROUGH, A. Report on the Explosives Industry in the Dominion of Canada. *Ibid.*, no. 92, 1911.

ELLS, S. C. Preliminary Report on the Bituminous Sands of Northern Alberta. *Ibid.*, no. 281, 1914.

—— Notes on Clay Deposits near McMurray, Alberta. *Ibid.*, no. 336 (*Bull.* no. 10), 1915.

FRECHETTE, HOWELLS. Western Portion of Torbrook Iron Ore Deposits, Annapolis County, Nova Scotia. *Ibid.*, no. 110, 1912.

—— Report on the Non-metallic Minerals used in the Canadian Manufacturing Industries. *Ibid.*, no. 305, 1914.

HAANEL, E. Report on the Mining and Metallurgical Industries of Canada 1907–8. *Ibid.*, no. 24, 1908.

—— Report on the Investigation of an Electric Shaft Furnace, Domnarfvet, Sweden, etc. *Ibid.*, no. 32, 1909.

—— Summary Report of the Mines Branch for the Calendar Year ending December 31, 1909. *Ibid.*, no. 63, 1910.

—— The Exploitation of our Peat Bogs for the Production of Fuel for Domestic and Industrial Purposes. Presidential Address 4th Annual Meeting, American Peat Society. *Ibid.*, no. 89, 1910.

—— Summary Report of the Mines Branch of the Department of Mines for the Calendar Year ending December 31, 1911. *Ibid.*, no. 142, 1912.

—— Report on the Utilization of Peat Fuel for the Production of Power, Being a record of experiments conducted at the Fuel Testing Station Ottawa, 1910–1911. *Ibid.*, no. 154, 1912.

CANADA. DEPARTMENT OF MINES, MINES BRANCH—*continued.*

HAANEL, E. Summary Report of the Mines Branch of the Department of Mines for the Calendar Year ending December 31, 1912. *Ibid.*, no. 224, 1913.

—— [*Idem*], 1913. *Ibid.*, no. 285, 1914.

—— Peat, Lignite and Coal: Their Value as Fuels for the Production of Gas and Power in the By-Product Recovery Producer. *Ibid.*, no. 299, 1914.

HUDSON, J. G. S. Sections of the Sydney Coal Fields, Cape Breton. *Ibid.*, no. 227 (Special Ed. Internat. Geol. Congress, 12th Sess.), 1913.

KALMUS, H. T. and Assistants. Researches on Cobalt and Cobalt Alloys, conducted at Queen's University, Kingston, Ontario, for the Mines Branch of the Department of Mines. Part I. *Ibid.*, no. 259, 1913.

KALMUS, H. T. and C. HARPER. [*Idem*] Part ii. The Physical Properties of the Metal Cobalt. *Ibid.*, no. 309, 1914.

LANE, A. C. Diamond Drilling at Point Mamainse, Province of Ontario. *Ibid.*, no. 111 (*Bulletin*, no. 6), 1911.

LEVERIN, H. A. Description of Commercial Methods and Apparatus for the Analysis of Oil Shales. Pp. 122–126 of Report no. 59, 1909. [See WAIT, F. G.]

LINDEMAN, E. Iron Ore Deposits of Vancouver and Texada Islands, British Columbia. *Ibid.*, no. 47, 1910.

—— Austin Brook Iron-bearing District, New Brunswick. *Ibid.*, no. 105, 1913.

—— Magnetite Occurrences Along the Central Ontario Railway. *Ibid.*, no. 184, 1913.

—— Magnetite Occurrences near Calabogie, Renfrew County, Ontario. *Ibid.*, no. 254, 1914.

—— Moose Mountain Iron-bearing District, Ont. *Ibid.*, no. 303, 1914.

LINDEMAN, E. and G. C. MACKENZIE. Iron Ore Deposits of the Bristol Mine, Pontiac County, Que. [Magnetometric Survey, etc., by E. L.: Magnetic Concentration of Ores by G. C. M.] *Ibid.*, no. 67 (*Bulletin*, no. 2), 1910.

MACKENZIE, G. C. Magnetic Concentration Experiments with Iron Ores of the Bristol Mines, Que., Iron Ores of the Bathurst Mines, New Brunswick, A Copper Nickel Ore from Nairn, Ontario. *Ibid.*, no. 82, 1910.

—— The Magnetic Iron Sands of Natashkwan, County of Saguenay, Province of Quebec. *Ibid.*, no. 145, 1912.

CANADA. DEPARTMENT OF MINES, MINES BRANCH—*continued.*

MACLEAN, T. A. Lode Mining in Yukon: An Investigation of Quartz Deposits in the Klondike Division. *Ibid.*, no. 222, 1914.

MCLEISH, J. Annual Report on the Mineral Production of Canada during the Calendar Year 1906. *Ibid.*, no. 26, 1909.

—— Annual Report of the Division of Mineral Resources and Statistics on the Mineral Production of Canada During the Calendar Years 1907 and 1908. *Ibid.*, no. 58, 1910.

—— [*Idem*] 1909. *Ibid.*, no. 88, 1911.

—— Preliminary Report on the Mineral Production of Canada during the Calendar Year 1910. *Ibid.*, no. 102, 1911.

—— Annual Report on the Mineral Production of Canada During the Calendar Year 1910. *Ibid.*, no. 143, 1912.

—— [*Idem*] 1911. *Ibid.*, no. 201, 1913.

—— Preliminary Report on the Mineral Production of Canada during the Calendar Year 1912. *Ibid.*, no. 216, 1913.

—— Annual Report on the Mineral Production of Canada During the Calendar Year 1912. *Ibid.*, no. 262, 1914.

—— Preliminary Report on the Mineral Production of Canada During the Calendar Year 1913. *Ibid.*, no. 283, 1914.

—— The Production of Iron and Steel in Canada During the Calendar Year 1913. *Ibid.*, no. 315, 1914.

—— The Production of Coal and Coke in Canada During the Calendar Year 1913. *Ibid.*, no. 316, 1914.

—— The Production of Cement, Lime, Clay Products, Stone, and other Structural Materials in Canada During the Calendar Year 1913. *Ibid.*, no. 318, 1914.

—— A General Summary of the Mineral Production of Canada During the Calendar Year 1913. *Ibid.*, no. 319, 1914.

—— Annual Report on the Mineral Production of Canada During the Calendar Year 1913. *Ibid.*, no. 320, 1914.

—— Preliminary Report [on] the Mineral Production of Canada during the Calendar Year 1914. *Ibid.*, no. 333, 1915.

NYSTRÖM, E. and S. A. ANREP. Investigation of the Peat Bogs and Peat Industry of Canada, during the Season 1908–9. *Ibid.*, no. 30 (*Bulletin*, no. 1), 1909.

PARKS, W. A. Report on the Building and Ornamental Stones of Canada. vol. i, 1912: vol. ii, Maritime Provinces, 1914: vol. iii, Province of Quebec, 1914. *Ibid.*, nos. 100, 203, 279.

PORTER, J. B., R. J. DURLEY, T. C. DENIS and E. STANSFIELD. An Investigation of the Coals of Canada with reference to their Economic Qualities: as conducted at McGill University,

CANADA. DEPARTMENT OF MINES, MINES BRANCH—*continued.*
Montreal, under the authority of the Dominion Government. *Ibid.*, no. 83 (in six volumes), 1912, 1913.

SCHMID, H. S. DE. Mica: its Occurrence, Exploitation, and Uses. *Ibid.*, no. 118 (Ed. 2), 1912.

WAIT, F. G. Report of Analyses of Ores, Non-Metallic Minerals, Fuels, etc., made in the Chemical Laboratories during the years 1906, 1907, 1908. *Ibid.*, no. 59, 1909.

WALKER, T. L. Report on the Tungsten Ores of Canada. *Ibid.*, no. 25, 1909.

—— Report on the Molybdenum Ores of Canada. *Ibid.*, no. 93, 1911.

WILSON, A. W. G. Pyrites in Canada: its Occurrence, Exploitation, Dressing, and Uses. *Ibid.*, no. 167, 1912.

—— The Copper Smelting Industries of Canada. *Ibid.*, no. 209, 1913.

Proceedings of Conference on Proposed Legislation to regulate the Manufacture, Importation and Testing of Explosives, held in House of Commons, Ottawa, Sep. 28 and 30, 1910. *Ibid.*, no. 89 [90], 1911.

Catalogue of Publications of the Mines Branch (1907–1911) [Tables of Contents of Reports, List of Maps, Digest of Memoirs and Summary Reports 1902–1906.] *Ibid.*, no. 104, 1912.

Economic Minerals and Mining Industries of Canada. *Ibid.*, no. 230, 1913.

Economic Minerals and Mining Industries of Canada. Special Edition for the Panama–Pacific Exposition, San Francisco, 1915. *Ibid.*, no. 322, 1914.

From the Secretary, Mines Branch.

CANADA. DEPARTMENT OF MINES, GEOLOGICAL SURVEY BRANCH.

ADAMS, F. D. and A. E. BARLOW. Geology of the Haliburton and Bancroft Areas, Province of Ontario. *Memoir* no. 6, 1910.

ALLAN, J. A. Geology of Field Map-area, B.C. and Alberta. *Ibid.*, no. 55, 1914.

BANCROFT, J. A. Geology of the Coast and Islands between the Strait of Georgia and Queen Charlotte Sound, B.C. *Ibid.*, no. 23, 1913.

BARLOW, A. E. Corundum, Its Occurrence, Distribution, Exploitation, and Uses. *Ibid.*, no. 57, 1915.

CANADA. DEPARTMENT OF MINES, GEOLOGICAL SURVEY BRANCH —*continued.*

CAIRNES, D. D. Preliminary Memoir on the Lewes and Nordenskiöld Rivers Coal District, Yukon Territory. *Ibid.*, no. 5, 1910.

—— Wheaton District, Yukon Territory. *Ibid.*, no. 31, 1912.

—— Portions of Atlin District, British Columbia; with Special Reference to Lode Mining. *Ibid.*, no. 37, 1913.

—— Moose Mountain District, Southern Alberta. *Ibid.*, no. 61, 1914.

—— The Yukon-Alaska International Boundary, between Porcupine and Yukon Rivers. *Ibid.*, no. 67, 1914.

—— Upper White River District, Yukon. *Ibid.*, no. 50, 1915.

CAMSELL, C. The Geology, and Ore Deposits of Hedley Mining District, British Columbia. *Ibid.*, no. 2, 1910.

—— Geology, and Mineral Deposits of the Tulameen District, B.C. *Ibid.*, no. 26, 1913.

CHAPMAN, R. H. Triangulation and Spirit Leveling of Vancouver Island, B.C., 1909. *Ibid.*, no. 11, 1910.

CLAPP, C. H. Southern Vancouver Island. *Ibid.*, no. 13, 1912.

—— Geology of the Victoria and Saanich Map-Areas, Vancouver Island, B.C. *Ibid.*, no. 36, 1913.

—— Geology of the Nanaimo Map-Area. *Ibid.*, no. 51, 1914.

COLLINS, W. H. The Geology of Gowganda Mining Division. *Ibid.*, no. 33, 1913.

DALL, W. H. and P. BARTSCH. New Species of Shells. *Ibid.*, no. 14, 1910.

DALY, R. A. Geology of the North American Cordillera, and Forty-Ninth Parallel. *Ibid.*, no. 38, 1912.

DODGE, C. K. Annotated List of Flowering Plants and Ferns of Point Pelee, Ont. and Neighbouring Districts. *Ibid.*, no. 54, 1914.

DOWLING, D. B. The Edmonton Coal Field, Alberta. *Ibid.*, no. 8, 1910.

—— Geological Notes to Accompany Map of Sheep River Gas and Oil Field, Alberta. *Ibid.*, no. 52, 1914.

—— Coal Fields of Manitoba, Saskatchewan, Alberta and Eastern British Columbia. (Revised Edition). *Ibid.*, no. 53, 1914.

—— Coal Fields and Coal Resources of Canada. *Ibid.*, no. 59, 1915.

DRESSER, J. A. Reconnaissance along the National Transcontinental Railway in Southern Quebec. *Ibid.*, no. 35, 1912.

CANADA. DEPARTMENT OF MINES, GEOLOGICAL SURVEY BRANCH —*continued*.

DRESSER, J. A. Preliminary Report on the Serpentine and Associated Rocks of Southern Quebec. *Ibid.*, no. 22, 1913.

DRYSDALE, C. W. Geology of Franklin Mining Camp, British Columbia. *Ibid.*, no. 56, 1914.

GOLDTHWAIT, J. W. An Instrumental Survey of the Shorelines of the Extinct Lakes Algonquin and Nipissing in Southwestern Ontario. *Ibid.*, no. 10, 1910.

HANDLIRSCH, A. Canadian Fossil Insects. *Ibid.*, no. 12, 1910.

KEELE, J. Clay and Shale Deposits of New Brunswick. *Ibid.*, no. 44, 1914.

—— Clay and Shale Deposits of the Western Provinces. Part V. *Ibid.*, no. 66, 1914. (See RIES, H.)

—— Preliminary Report on the Clay and Shale Deposits of the Province of Quebec. *Ibid.*, no. 64, 1915.

LAWSON, A. C. The Geology of Steeprock Lake, Ontario. *Ibid.*, no. 28, pp. 1–15. 1912. (See WALCOTT, C. D.)

—— The Archaean Geology of Rainy Lake, Restudied. *Ibid.*, no. 40, 1913.

LE ROY, O. E. The Geology and Ore Deposits of Phœnix, Boundary District, British Columbia. *Ibid.*, no. 21, 1912.

—— Mother Lode and Sunset Mines, Boundary District, B.C. *Ibid.*, no. 19, 1913.

MCCONNELL, R. G. Portions of Portland Canal and Skeena Mining Divisions, Skeena District, B.C. *Ibid.*, no. 32, 1913.

—— Texada Island, B.C. *Ibid.*, no. 58, 1914.

MCINNES, W. The Basin of Nelson and Churchill Rivers. *Ibid.*, no. 30, 1913.

MALCOLM, W. Gold Fields of Nova Scotia. *Ibid.*, no. 20, 1912.

—— Oil and Gas Prospects of the Northwest Provinces of Canada. *Ibid.*, no. 29, 1913.

MALLOCH, G. S. Bighorn Coal Basin, Alberta. *Ibid.*, no. 9, 1911.

O'NEILL, J. J. St. Hilaire Beloeil and Rougemont Mountains, Quebec. *Ibid.*, no. 43, 1914.

RIES, H. Clay and Shale Deposits of the Western Provinces. Parts III & IV. *Ibid.*, nos. 47 & 65, 1914. (See KEELE, J., and below.)

RIES, H., and J. KEELE. The Clay and Shale Deposits of Nova Scotia and Portions of New Brunswick. *Ibid.*, no. 16, 1911.

——, —— Preliminary Report on the Clay and Shale Deposits of the Western Provinces. Parts I & II. *Ibid.*, nos. 24 & 25 1912, 1913.

CANADA. DEPARTMENT OF MINES, GEOLOGICAL SURVEY BRANCH —*continued.*

SPRINGER, F. On a Trenton Echinoderm Fauna at Kirkfield, Ontario. *Ibid.*, no. 15, 1911.

STOPES, M. C. The "Fern Ledges" Carboniferous Flora of St. John, New Brunswick. *Ibid.*, no. 41, 1914.

WALCOTT, C. D. Notes on Fossils from Limestone of Steeprock Lake, Ontario. *Ibid.*, no. 28, pp. 16–22, 2 pls. 1912. (See LAWSON, A. C.)

WILLIAMS, M. Y. Arisaig-Antigonish District, Nova Scotia. *Ibid.*, no. 60, 1914.

WILSON, A. W. G. Geology of the Nipigon Basin, Ontario. *Ibid.*, no. 1, 1910.

WILSON, M. E. Geology and Economic Resources of the Larder Lake District, Ont., and adjoining portions of Pontiac County, Que. *Ibid.*, no. 17, 1912.

—— Kewagama Lake Map-Area, Quebec. *Ibid.*, no. 39, 1913.

WILSON, W. J. Geological Reconnaissance along the line of the National Transcontinental Railway in Western Quebec. *Ibid.*, no. 4, 1910.

YOUNG, G. A. Bathurst District, New Brunswick. *Ibid.*, no. 18, 1911.

Report of the Commission appointed to investigate Turtle Mountain, Frank, Alberta, 1911. *Ibid.*, no. 27, 1912.
From the Secretary, Geological Survey Branch.

CASSIER'S ENGINEERING MONTHLY, vol. xlvii, nos. 4–6.
From Arthur W. Eastlake.

DANBY, A. Natural Rock Asphalts and Bitumens. 8vo, *London*, 1913. *From Sir T. B. Bowring.*

GAS AND OIL POWER, vol. x, nos. 111—117. *From the Publishers.*

GEIKIE, Sir A. Textbook of Geology. Ed. iv. 8vo, *London*, 1903.
From Sir T. B. Bowring.

GEIKIE, Dr. J. Structural and Field Geology for Students of Pure and Applied Science. Ed. iii. 8vo, *London*, 1912.
From Sir T. B. Bowring.

IMPERIAL INSTITUTE, BULLETIN, vol. xiii, pt. 1. *From the Director.*

INDIA, GEOLOGICAL SURVEY, RECORDS, vol. xliv, pt. 4: vol. xlv, pt. 1. *From the Director.*

INGLE, H. A. A Manual of Oils, Resins, and Paints, for Students and Practical Men. Vol. i. 8vo, *London*, 1915.
From Sir T. B. Bowring.

INSTITUTE OF MINING AND METALLURGY, BULLETIN, nos. 121–129. *From the Secretary.*

KAHNCRETE ENGINEERING, vol. ii, nos. 2, 3. *From the Publishers.*

OIL AGE, vol. xi, nos. 1–5. *From the Publishers.*

ROYAL SOCIETY OF ARTS, JOURNAL, vol. lxiii, nos. 3252—3266. *From the Publishers.*

THORPE, Sir E. Dictionary of Applied Chemistry. n. ed. 5 vols. 8vo, *London*, 1912, 1913. *From Sir T. B. Bowring.*

TINKLER, Dr. C. K. and Dr. F. CHALLENGER. The Chemistry of Petroleum and its Substitutes. 8vo, *London*, 1915. *From Sir T. B. Bowring.*

UNITED STATES GEOLOGICAL SURVEY OF THE TERRITORIES. 8vo, *Washington.*

12th ANNUAL REPORT (atlas of maps and panoramas only). 1878.

—— GEOLOGICAL SURVEY. 8vo, *Washington.*

8th	ANNUAL REPORT.	Pt. 2.	1886–1887.
17th	„	Pt. 3.	1895–1896.
19th	„	Pt. 6.	1897–1898.

From Arthur W. Eastlake.

WELLS, J. Wire Ropes on the Oilfields. 8vo, *London*, 1915. *From the Author.*

EXCHANGE LIST.

The following is the list of Institutions, etc., with whom we exchange publications.

1. Australia, High Commissioner.
2. Canada, Department of Mines, Geological Survey.
3. „ „ „ „ Mines Branch.
4. Gas and Oil Power.
5. Imperial Institute.
6. India, Geological Survey.
7. Institute of Chemistry.
8. Institution of Mining and Metallurgy.
9. Iron and Steel Institute.
10. Kahncrete Engineering.
11. Oil Age.
12. Oil Exchange.
13. Royal Society of Arts.

The Journal is also forwarded to the British Museum, Copyright Department, and to the Patent Office Library.

Advertisements in the Journal. A limited number of advertisements of firms interested in the Petroleum Industry, may be inserted in the Journal. Applications for terms, etc., should be made to the Secretary.

LIST OF ADVERTISERS.

(Members are desired, when making enquiries or placing orders with advertisers, to mention that they have seen their announcement in the Journal).

W. J. Fraser & Co.
Oil Well Supply Co.
University of Birmingham.
W. H. Willcox & Co., Ltd.

PERSONAL NOTES OF MEMBERS, AND SPECIAL NOTICES.

It is suggested that Members of the Institution send information regarding their movements to the Secretary for insertion under this heading.

Another valued Member of our Institution has recently passed away, and we are favoured by our Associate Member, Mr. C. B. Brown, with the following account of his life :—

Sketch of the career of The late Mr. John Donald Campbell.

Mr. Campbell was born on September 1st, 1866, in the parish of Ballingry, Lochgelly, Fifeshire, his father, Mr. John Campbell, being foreman at the works of the Cowdenbeath Colliery. He died at Lobitos, Peru, on April 3rd, 1915.

In his boyhood he was attracted, as most boys are, by a life of adventure, and was possessed with a longing to go abroad to strange lands : he always preserved his love of reading books of travel. He was studious as a young man, and whilst serving his apprenticeship at engineering works in Dunfermline and Kirkcaldy, attended evening classes, and read assiduously in his spare time. At an early age he worked in the Great Western Railway Company's

works at Swindon as a turner, where he remained several years. Tiring of this somewhat humdrum and unadventurous life, he went out to the Argentine, where he had some experience of a revolution at Mendoza, suffering imprisonment through a mistake on the part of the revolutionaries.

After spending a short time at home, he returned to South America, this time to Peru, working at the erection of the refinery of the London and Pacific Petroleum Co., Ltd., at Talara in the Negritos Oilfields, Peru.

Some nine or ten years later began his most important work, the development of the Lobitos field in the Tumbez province. He was appointed manager of the Lobitos Oilfields, then known as the Peruvian Petroleum Syndicate, Limited, by Mr. Alexander Milne, in 1905, when this oilfield was in its infancy, consisting of some half-dozen shallow wells and one or two huts. From that date to the time of his death he worked hard at the development of the field, and the efficiency of his work may be gauged by a review of the field as it stands to-day: containing, as it does, more than two hundred drilled wells; equipped with every appliance for the prosecution of such an extensive industry—a large factory (in which, of course, he took the greatest interest), offices, stores, dwelling-houses, storing-tanks, landing mole and so forth—and with a thoroughly organised staff for every branch of the work.

Although he had never actually worked "on tour," he had an intimate knowledge of well-drilling: indeed, there were few problems in the sinking of a well for which he was unable to find a solution. By his dogged pertinacity, he made successes of many wells which a man of smaller ability would have abandoned in despair as failures. He was particularly enthusiastic about drilling deep for oil; a policy which has been entirely justified in the case of Lobitos. The reverse of conservative in his methods, Mr. Campbell was always seeking after new ideas, and tried both the rotary and the Canadian system of drilling, bringing drillers from Galicia for the latter. In order to gain a thorough practical knowledge of these systems, he spent part of his well-earned holidays in California and Galicia.

His interest in all that belonged to petroleum mining showed itself in the well-equipped laboratories and offices for the varied scientific work of the field. He interested himself alike in the geological, chemical and topographical aspects of his work. He had an enthusiastic faith in the future of the company, and was eager for the extension of its activities, which he spared no energy to promote.

Mr. Campbell was a man of strong personality: although, like all strong men, he had a few enemies (who could not fail to admire his capabilities), he had a vast number of friends, who deeply deplore his early death; for he was, perhaps, the most widely known man in Northern Peru. Always he was a kind-hearted man and a true friend; and to those who had the good fortune to know him well, there will be always something lacking in their sojourn on that far-away coast.

He had the secret of managing men, especially the natives, who, although they stood in awe of him, had a great respect and liking for "*el Gerente*." Through many difficulties, such as strikes of the workmen, which he experienced more than once, he invariably came victorious by his firm and just handling of the situation. By his keen foresight, his absolute fearlessness and his power of quick decision at critical moments, he was singularly qualified to fill his difficult and responsible post. Taking him for all in all, his equal will be hard to find.

During a residence of nineteen years on the Pacific Coast he had gained an intimate knowledge of the country and its inhabitants from Valparaiso to Tumbez. Nor was his experience confined to this coast; he had travelled in Ecuador, and had worked in South Africa and the United States of America. But his life's work lay in Peru, at Lobitos, which he loved and in which he took a pride as a father. He leaves his own visible monument in these fields, which he may, in a technological sense, be said himself to have created; his invisible monument in the hearts of his many friends.

He is buried, where he would have wished, in the little cemetery of the field away at the foot of the hills along the coast, under the blue skies and blazing sun of Peru: with the surge of the Pacific beating on the solitary shores, and the cry of the sea-birds to lull him to sleep.

The funeral was an impressive demonstration of the respect and affectionate esteem in which he was held by all those among whom he had worked with such success for many years. One who was present writes that the procession was headed by eighty school-boys bearing torches (the interment was at 9 p.m. on Easter Sunday), and by the brass band, in which the deceased had taken great interest; and was followed by a great assemblage of the people of Lobitos. The service was conducted by the British Vice-Consul, who came from Paita for that purpose, and a short address of eulogy was delivered by Mr. Wilfrid Burford, the Assistant Manager of the Company.

We regret to hear, as we go to press, of the death of Mr. WILLIAM EVANS, also one of our original members.

The Secretary will be glad to learn the present address of Mr. JAMES T. ARMSTRONG, late of 22, Great St. Helens, London, E.C.

Captain R. W. BARNETT is attached to the General Staff as Staff Officer for Musketry.

Mr. L. J. BATES has joined the 18th Royal Fusiliers, D Co.

Dr. T. O. BOSWORTH is paying a lengthy visit to Canada.

Mr. C. B. BROWN is 2nd Lieutenant in the 19th Royal Fusiliers.

Captain D. M. CHAMBERS is in the 16th Durham Light Infantry.

Mr. E. H. CUNNINGHAM CRAIG is acting as honorary Instructor in map-reading, mapping, and field-sketching to the 62nd Brigade.

Lieut. C. W. DAVSON is in the Royal Garrison Artillery.

Mr. A. DUCKHAM returned from a visit to Trinidad early in April.

Lieut. G. W. EDWARDS is with the 9th (S) Border Regiment Pioneers.

Mr. W. H. FORDHAM is 2nd Lieutenant in the Royal Field Artillery, 22nd Division.

Mr. T. R. H. GARRETT is a 1st class Petty Officer in the Royal Navy Armoured Car Division, No. 5 Squadron.

Mr. G. W. HALSE is 2nd Lance Corporal in the 2nd Signal Co., Canadian Expeditionary Force.

Dr. J. A. LEO HENDERSON returned from Canada in May.

Mr. F. A. HOLIDAY arrived in London from Mexico early in April.

Sir T. H. HOLLAND is Major and Commandant in the Manchester University Contingent, Officers' Training Corps.

Mr. S. LISTER JAMES is still in Trinidad.

Mr. BASIL F. N. MACRORIE expected to return to England in May from Persia.

Mr. C. TEMPLE ORME returned to this country from Galicia, in March.

Lieutenant Commander C. C. PEATY has resumed service in the Royal Navy.

Mr. I. C. REDWOOD is 2nd Lieutenant in the 2/2nd H.C.Fd.Co., Royal Engineers.

Lieut. I. A. STIGAND is in the 5th Royal West Kent.

Mr. A. F. STRICKLAND has entered the Royal Naval Division.

Mr. W. SUTTON, having visited Mexico, returned from the United States of America at the beginning of April.

Mr. J. M. WHYTE has returned to this country from Mexico.

We are glad to hear that Prof. CADMAN, who has been seriously ill, is making satisfactory progress towards recovery.

NEWLY ELECTED MEMBERS.

Members.—George Thomas Holloway, Richard Gillies Neilson, Maurice Albion Ockenden, Francis Russell, Stephen Frank Stackard, Charles Willans.

Associate Members.—Luis de Florez, Robert Bertram Grey, Harold Edgar Keary, Richard Roy Lewer, John Edward Lloyd Strevens, Robert Reginald Thompson, Carter White.

Students.—Burton Dunglinson, Charles Walter Hodsdon, Launcelot Owen.

Associate.—James Solomon Blanckensee.

The total membership now consists of:—

Honorary Members	4
Members	105
Associate Members	52
Students	18
Associates	9
	188

PROPOSED DINNER AND LUNCH CLUB, IN CONNECTION WITH THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

The formation of this Club is projected with the object of enabling members to dine together before each Meeting, and to lunch together a few days later, so that they may thus have the opportunity of informally discussing various subjects brought to their notice.

Members will be entitled to introduce guests, on giving due notice to the Hon. Secretary.

The subscription will be a nominal one, as it is only intended to defray the cost of printing and postage.

The Club will not be formed unless at least thirty members signify their intention to join it. More than twenty have already agreed to do so.

Mr. Ashley Carter, of Dashwood House, New Broad Street, E.C., has kindly consented to act as Hon. Secretary to the Club.

EDITORIAL.

Drilling Logs.

In virgin oil-fields, where the relative positions of oil-sands, water-sands, impervious clays, boulder-beds, caving beds, and all other geological advantages or hindrances, are equally unknown, awaiting future revelation by the drill, accurate record of the material penetrated is of paramount importance. The value of information of this character, which has been lost through sheer neglect and ignorance, probably far exceeds that of the oil wasted through similar causes. The duly-kept log of a dry hole may be of greater ultimate value than the result of a giant spouter of which no record remains but of its depth and yield. The financial short sight which can read only immediate balance-sheets may fail to realise this important verity, yet the rational working of an oilfield demands, as a primary essential, a grasp of the subterranean conditions only to be had by assiduous collection of all obtainable details of information.

Unfortunately many drillers have yet to learn that an intelligible record of their work is a most important element of their duty in new fields and on the unproved margins of those already but partly developed. They are prone to imagine that skill and experience in mechanical operations, instead of conferring a position but comparatively inferior, is the final stage of perfection in their calling. Inflated with the fact of their importation across perhaps half the width of the globe, they incline to assume themselves past all further instruction, even in matters of which they have grasped but the feeblest conception.

What geologist, arriving in a region previously unknown to science, and of which the surface was draped in virgin forest, would dare to express off-hand an opinion on its internal structure or mineral wealth? But the imported driller, relying possibly on slight botanical analogies with fields familiar to him, will, with fatuous assurance, pronounce the ground he has just set eyes upon, to be as fine an oilfield as it has been his happy lot to visit, and predict that rich yield will ensue upon brief drilling in some indicated spot. The expression of this profound judgment, conveyed to his direct principals, is passed forward to the gratified financiers, and duly announced, although of less value than the printing ink wasted on it.

When such drillers are ordered to submit records, they have been known to display their intense ignorance of the true purpose of their work by the assertion that their business is to "make holes, not books"—and accordingly we find one week's run entered as "clay, so much," that of the next as "rock, so much," clearly showing the "record" to have been left to the week-end, and to be a mere work of fiction: indeed the nautical term "lies like a log" is much more often applicable to mendacity of drilling records than to inertia of marine flotsam.

When an unfortunate geologist is called upon to determine, from such concoctions as these, the structural relations of the several wells and of the surrounding area, the "evidence" is usually so conflicting that he might almost justifiably seek to decide the truth by the toss of a coin, as jurymen are said to have done in similar dilemmas. The assumption of the self-neutralisation of error, and resulting emergence of truth, may, like the mathematician's averages and means, afford accordance with theory, but is assuredly unsatisfactory as a basis for practice. Of the drillers of a pair of wells under comparison, one may have predilections in favour of clay, the other of rock, in posting their respective recollections of the week's mixture. Or one may have a more vivid remembrance of the earlier, the other of the later, part of the week. There are, of course, other considerations than such "personal equations," but equally repugnant to the reposing any reliance upon logs which habitually record variation of material at the precise termination of the week's work. A Persian-Gulf captain has been heard to declare that when a pilot, from a heave of the line and a sniff at the lead, states a certain position on the chart, the vessel is certainly *not* at that point, and in like manner we can feel sure that rock-changes do not occur when no work is in progress, so as to present variety for Monday.

Were this falsification of logs (for no milder term is applicable) encountered by its merited reprehension and discredit on the part of superintendents, there might result at least an attempt at correct record of details.

It may not, indeed, be practicable, when drilling at speed, to take measurements of any great degree of exactitude, although a skilled driller should be instantly aware of reaching a difference of material, but it is of importance that all such changes should be recorded with as near an estimate of their position as circumstances permit, and they should not be left to the wearied memory

at the close of the day, still less of the week. The soiled record made at the time is far preferable to the neat fiction usually substituted for it.

The several printed forms of logs, advanced as examples of how such records should be kept, have generally grave defects. The words Rock and Stone, for instance, convey nothing of importance without indication of the nature of the material, and are superfluous if that nature is stated, as sandstone, limestone, flint, pyrites, &c. Clay and shales again, practically identical material, differing merely in texture, are generally separated. The result is that the log at a glance is geologically unintelligible, differences in one case, and identity in the other, being masked by the irrational mode of presentation. In some fields there are but two classes of material, the clays (or shales) and the sandstones or limestones (as the case may be, but not both). Where this is definitely known, the word rock (or stone) is of course less objectionable, as leaving little or no ambiguity.

Destructive criticism, however, is a much simpler task than reconstructive suggestion, and it is by no means easy to evolve a form of log suitable to every conceivable series of petroliferous deposit. It must be borne in mind that the information has to meet the requirements both of the engineer and of the geologist, and these coincide in but few points. The engineer wants principally particulars of the rate of progress, the wear of tools, the tendency to jam or cave, the position of water-bearing beds and of such as are favourable for setting casing. The geologist wants the character of each different bed penetrated, and its thickness, at least approximately, as a basis of identification from point to point, of characteristic strata that may serve to define the structure of the field where this is masked by superficial deposits, or to correct the conception of the structure as formed by calculation from surface evidence.

One salient point is clear, that it is impossible to have too much detail, provided that it be truthfully recorded. It is of small detriment if unimportant variations are noted in what might safely be regarded as a homogeneous mass, *e.g.* slight changes of colour or texture. On the other hand, the lumping of a great thickness of strata as "clay and stone" is a nullification of the information that it professes to convey. A few feet of frequent alternations, separating continuous masses of either material, may represent the position of a recognisable bed of either

description, and therefore should be recorded. That is, a definite bed of sandstone between clays, or of clay between sandstones, may tail out into a group of thin-bedded alternations, and yet continue to mark the original horizon in the series. It is better for the driller to risk waste of time in recording possibly trivial changes than merely to remember indistinctly their occurrence when their exact position is subsequently inquired for as important.

In like manner, several beds especially suitable for setting casing may be passed without need of that advantage, but it may happen that in another part of the field, a water-bearing rock may come in by lateral variation, necessitating shut-off at a higher horizon than previously, and for this the known position of good horizons for setting would be most valuable.

All printed forms of record have the common drawback of inadequate space for casual expansion of detail. The only safety-valve is the Remarks column, in which reference can be made to details given on another sheet of paper.

In view of the vast importance of true and full logs, equally to engineer and geologist, it is proposed to hold, at some convenient time in the course of our next session, a symposium on the possibility of drafting a form of log capable of receiving all required data, and without overtaxing the comprehension of the operatives whose duty, probably more or less unwelcome at first, would be the correct entry of the particulars specified, and of any other information that increasing intelligence might suggest as useful, though not "so nominated in the bond." Members wishing to take part in the conference, or to contribute their views in writing, are invited to communicate with the Hon. Secretary.

Fifth General Meeting.

A Meeting of the Institution of Petroleum Technologists was held at the House of the Royal Society of Arts on Thursday Evening, 18th March, 1915, Sir Boverton Redwood, Bart., D.Sc., F.R.S.E. (President), occupying the chair.

The Members of Council present were Mr. Edwin R. Blundstone, Mr. Arthur W. Eastlake, Mr. T. C. Palmer, and Dr. F. Mollwo Perkin.

The Hon. Secretary announced that letters regretting their inability to attend the meeting had been received from Professors Cadman and Lewes.

The following paper, illustrated by lantern-slides, was read :—

The Internal-Combustion Engine on the Oil Field.

By F. G. Rappoport, Assoc.M.Inst.C.E., M.I.Mech.E., *Member*.

The efficient installation of power plant is one of the most important problems with which the oil technologist has to deal.

The object of this paper is to state the advantages and limitations of the internal-combustion engine as a source of power for oil-field purposes, and its relation to other forms of power, and to ventilate a subject upon which there is a certain lack of unanimity amongst oil-field engineers. The practical data given have been obtained from experience in the Russian oil-fields, where this form of power has made considerable progress of late years.

Steam-power and electricity will be briefly reviewed before proceeding to discuss the internal-combustion engine itself.

As shewing the great possibilities in fuel economy, which is one of the factors in the application of the internal-combustion engine, the following table (1) gives some statistics relating to the Baku oil-field for twelve years past.

The most important column is No. 6, setting forth the value of the oil used as fuel. This amounted in 1913 to nearly three million pounds sterling. It is obvious that every per cent. of this amount saved means a considerable economy.

It will be noted incidentally from column 4 that the percentage of the production used as fuel has actually increased latterly, in spite of economical introductions. The reason for this is that the fuel, being expressed as a ratio to the net production of oil, is not a fair expression of the actual quantity of *liquid* raised by means

of this fuel expenditure. Water in large quantities has now to be raised with the oil. In the earlier years fountains were of more frequent occurrence than they are now, this also tending to keep down the fuel expenditure at that time.

TABLE I. STATISTICS OF THE BAKU OIL-FIELD.

1	2	3	4	5	6	7	8
Year.	Production by Baling in Poods.	Fuel used in Poods.	% of Fuel to Production.	Price of Oil in Copecks.	Value of Fuel used in £ Sterling (approx.)	Number of Producing Wells.	Number of Drilling Wells.
1902	636,529,000	66,050,000	10·4	6.72	444,000	1840	
1903	596,605,000	63,820,000	10·7	9.01	602,000	1850	
1904	615,022,000	69,340,000	11·3	14.67	1,070,000	2011	
1905	409,925,000	46,930,000	11·4	19.93	985,000	1989	
1906	448,374,000	48,440,000	10·8	25.56	1,300,000	1970	235
1907	476,470,000	62,130,000	13·1	27.67	1,500,000	2260	235
1908	467,312,000	74,884,000	16·0	21.62	1,700,000	2456	271
1909	490,966,000	66,540,000	13·6	21.04	1,500,000	2601	232
1910	478,181,000	65,007,000	13·6	15.05	1,020,000	2787	214
1911	425,212,000	65,139,000	15·3	22.69	1,475,000	2825	139
1912	419,003,000	63,396,000	15·1	34.82	2,300,000	3193	229
1913	390,324,000	58,605,000	15·0	42.70	2,600,000	3445	225
1914	338,600,000						

The type of steam-power plant usually found on an oil-field is, from a thermodynamic point of view, highly inefficient, and entails a high fuel consumption per unit of power generated. The following are the reasons for this inefficiency:—(1) The use of low-pressure steam in simple non-condensing engines. (2) The use, frequently, of cold feed-water. (3) Long lines of piping between boiler and engines, and consequent loss by condensation. (4) Bad water, often, necessitating frequent blowing down, and attendant loss of heat; the formation of scale, and consequent loss through defective conduction.

An average plant of this nature will use from 60 lb. to 75 lb. of steam per E.H.P. per hour.

Other disadvantages than the thermal ones above stated are :— (1) The necessity for a large water-supply near the oil-field. (2) The large amount of valuable space occupied by the boiler plant. (3) Danger from fire due to the presence of the boiler houses in close proximity to the wells. (4) Large staff and cost of upkeep.

Improvements are frequently installed in the shape of feed-water heaters, superheaters, well-lagged steam-pipes, increased boiler pressures, and some forms of condensation, but as a whole the plant is, by its very nature, uneconomical and inefficient. All forms of steam-power have a comparatively low thermal efficiency. In the best types of steam-plant, which, as far as oil-field work is concerned, could only be used in conjunction with electric power, this thermal efficiency does not exceed 21 %. Under the average oil-field power-conditions first described, the corresponding thermal efficiency will not exceed 5 %, and 3 % is probably nearer the mark.

An oil-field develops gradually, well by well, from the prospecting stage, through that of development, to finally what may be termed the mature stage, when the oil-field becomes commercially productive.

Steam-power adapts itself to such piecemeal system of development. The plant can be conveniently and quickly installed, and can be added to as development proceeds. The capital outlay therefore keeps pace with development. To those who are conversant with the uncertainties of oil-field development these are important considerations.

But the greatest practical advantage which steam-power possesses is its elasticity and flexibility in readily and quickly responding to the intermittent power-requirements, for which the character of oil-field work calls. In boring, changes of speed are constantly required at short notice. Wells must be baled at varying speeds, so as to maintain that steady head of liquid, necessary in order to avoid sand plugs. The very character of baling involves a constantly changing speed, from the position of rest at the bottom, when the maximum power must be exerted in order to start the baler, to the steady speed whilst the baler is rising through the liquid, and the high speed finally required to draw the baler quickly through the free space. All these fluctuations demand a type of motor which will readily and instantaneously respond to them. Owing to its ready adaptability to such changes of speed and power as required, the steam-engine still largely holds its own against other more economical types of power, which are not so satisfactory in this respect.

TABLE II. RELATIVE USE OF DIFFERENT FORMS OF POWER IN THE BAKU OIL-FIELDS.

Kind of Power.	1910.		1911.		1912.		1913.	
	Number of Wells.	% of Total	Number of Wells.	% of Total	Number of Wells.	% of Total	Number of Wells.	% of Total
Steam	2341	78	2173	73	2171	64	1683	46
Electric	361	12	440	15	657	19	1002	27
Oil Engine	240	8	295	10	469	14	893	24
Gas Engine.....	59	2	56	2	125	3	92	3
Total number of wells	3001		2964		3422		3670	

Kilowatt hours used.		Particulars of one of the Central Electric Stations.	
1906	20,382,146	Steam pressure	200 lbs. per sq. inch.
1907	25,257,579	Steam used.....	18·2 lbs. per I.H.P. hour.
1908	29,904,764	Total horsepower ..	7000
1909	31,915,945	Chimney temp.	135°C.
1910	37,466,396	Cooling surface	2 sq. ft. per H.P.
1911	34,119,540	Fuel used	1·2 lbs. per I.H.P. hour.
1912	53,771,601	Make-up water ..	8 %
1913	79,785,554		

Steam-power further possesses that advantage, due to centralization, which enables the horse-power of the central plant to be of the average power required over the whole system.

To sum up then, in its production, steam-power is highly inefficient and uneconomical. In its adoption, owing to its flexibility, it is ideal.

In striving for economy by other forms of power, this quality of flexibility, so admirably possessed by the steam-engine, must not be lost sight of, but must be aimed at.

Electric power is now coming widely into use in many large oil-fields.

One of its most important advantages is that the central power-station is independent of the position of the oil-field. The most suitable site can therefore be selected in point of water-supply and other facilities. This also means decreased danger from fire, the plant in the oil-field itself being limited to the electric motor at the well. As a result of this centralization, the most efficient steam plant, using high-pressure steam, etc., can be used to produce the electric energy, and the consumption of steam can be reduced to about 12 lbs. per I.H.P. hour. This form of power is therefore cheaper than the ordinary steam-power now used on the oil-field. The personnel required is comparatively small, as the motors do not require constant attention.

It is a form of power which essentially typifies the principle of centralization, with the consequent advantage of the reduction of the total power to be generated at the central station to the average power required over the system. The best results are therefore obtained when this power is utilised on a large scale, and it is consequently not a practicable form of power for the prospecting or early development stages of the life of an oil-field.

In its actual adoption at the well, by means of the constant-speed electric motor, electric power does not possess that advantage of flexibility, enjoyed in so ideal a manner by the steam-engine. This is the disadvantage of all constant-speed motors, and this point will be further dealt with when discussing the internal-combustion engine.

Electric power is usually supplied by a separate commercial undertaking. The advantage of a supply of power, available on the spot, eliminates the necessity of large initial capital outlay on power plant.

That the many advantages of electric power are fully recognized is shown practically by the enormous strides made in its use in various oil-fields. In the Baku oil-field, for instance, the output

of electric energy increased from twenty million kilowatt hours in 1906, to over fifty-three million in 1912 and to nearly eighty million in 1913.

Amongst other data given in this table, it will be seen that the use of electric power in the Baku oil-field shews a progressive increase. The figures of steam and fuel consumption given at the bottom of the table shew the economy which can be effected by using this form of power.

Electric power, therefore, as compared with steam-power is considerably more economical and efficient in its production. This economy and efficiency will no doubt be still further increased in the future by the use of high-compression or medium-compression (Diesel or semi-Diesel) internal-combustion engines in place of steam-power. In its actual adoption at the well, however, electricity lacks that flexibility of transmission, which makes steam-power so convenient.

Further advantages in its use are cleanliness, less danger from fire, less labour, and conservation of valuable space.

Coming next to the consideration of internal-combustion engines, we have first to deal with the crude-oil engine. Since the introduction of the medium-compression (semi-Diesel) type of crude-oil engine during the last ten or twelve years, the use of this engine has rapidly increased on the oil-fields. This has been the experience on the Russian oil-fields, where it has been largely adopted.

The present-day oil-engine is a more efficient heat engine than the most efficient steam-engine. Indicated thermal efficiencies of 30 % are quite usual, and 35 % to 37 % are readily obtainable, as against 21 % with the best steam-plants, such as would be used for generating electric power in the oil-fields, and as against the 3 % to 5 % efficiency of the steam-plant ordinarily in use in oil-fields.

The oil-engine consumes from a fifth to a tenth of the fuel which a steam-plant of corresponding power requires. From a half to three-quarters of a pound per B.H.P. hour is the usual consumption. As far as economy in fuel is concerned the oil-engine may be considered ideal. Besides its thermal superiority, the oil-engine can compete with the steam-engine in all stages of oil-field development. The question of water, paramount in all steam-power plants, practically disappears with the use of the internal-combustion engine, as the quantity used by the latter is limited to that required for cooling purposes. The number of employees

required to run this type of plant is probably somewhat less than for steam-power, but greater skill and attention are required.

The advantages of the crude-oil engine may therefore be thus summarized: (1) Minimum fuel consumption per unit of power. (2) It can be installed in all stages of oil-field development and exploitation, on a large or small scale. (3) It occupies a minimum of space in proportion to the power developed. (4) It is clean and safe, and not costly to maintain, provided the supervision is good.

We now come to the practical difficulties and limitations of the internal-combustion engine as a form of power in the oil-field.

It must be remembered that the medium-compression (semi-Diesel) oil-engine has been in use for only a comparatively short time. The progress in introducing this power laboured under the same disadvantage against which electric power had to contend, viz., that of competing with established and familiar forms of power. The conditions most suitable for the internal-combustion engine had to be determined by actual experience.

The fundamental disadvantage in the present method of using oil-engines on a large scale in the oil-field is the decentralization of the whole power plant.

The plant is installed in separate, scattered units at each well. This means increased danger from fire, and increased supervision and labour.

Under such conditions the total power laid down must be equal to the maximum power, and therefore greater than the average power of centralized plants. The reduction in total power, effected in centralized plants by equalization of "peak" loads, is therefore unobtainable.

Each unit installed must be capable of dealing with the varying power required at the particular well, both in boring and baling operations. A great mistake made in the early days was to underestimate the requisite power of the engines, by providing for average needs only. This mistake resulted from experience with the steam-engine, which by its flexibility in speed was able to supply maximum or overload power. Oil-engines must therefore be installed rated for the maximum powers that may be required. This means a greater initial cost on account of the higher power of engine necessary, and a slightly increased fuel-consumption per horsepower due to normally running below the rated power. The fuel-economy is however so great, that this increase in capital and running costs is not of material importance.

Particular attention should therefore be paid to the accurate determination of the maximum powers required when installing oil- or gas-engines.

The constant speed of oil motors is the chief practical difficulty in their use on the oil-field. As has already been explained when discussing steam-power, oil-field operations require continual variations in speed. In oil-fields where baling is the chief means of oil production, the life of the wells depends upon close attention to the rate of baling, in order to maintain that head of liquid in the well, which will allow free entrance of the largest quantity of oil through the sand stratum, and, at the same time, prevent the sand itself from rising and plugging the bore. In drilling, the regulation of the number of blows per minute is important in a rock-series of varying hardness. The freeing of a column of casing which has become fast may require momentary increase of power, applied without delay. There is, unfortunately, as yet no satisfactory method by which instantaneous variations of speed can be obtained when using oil-engines or other constant speed motors. In other words, although the gain in economy by the use of oil-engines is enormous, yet the application of this power is still in a primitive state, as far as regards the requirements of oil-field work. The gain in economy is however so important that attempts to overcome the difficulties of its application are becoming more and more serious.

Some of the latest types of engine can now be regulated to increase the speed by $2\frac{1}{2}$ % above, or 5 % below the normal.

Working on different lines, attempts are now being made at a return to centralization by using one high-power engine to drive several wells. Greater flexibility is thus attained, and the total power required is lessened by equalization of " peak " load. The writer has lately been informed that some enterprising firms in the Baku oil-field are now arranging their derricks in such lines that the power of one sufficiently powerful motor can be delivered through one long transmission to several wells, and that this principle is being still further extended by the use of wire-rope transmission to cover long distances.

The use of compressed air has been suggested, and has in fact been tried, but further trial is necessary. The initial cost is, however, great.

This important matter is thus still in the experimental stage, and possibly the solution of the difficulty may lie along the lines indicated, and the return to central power-station conditions

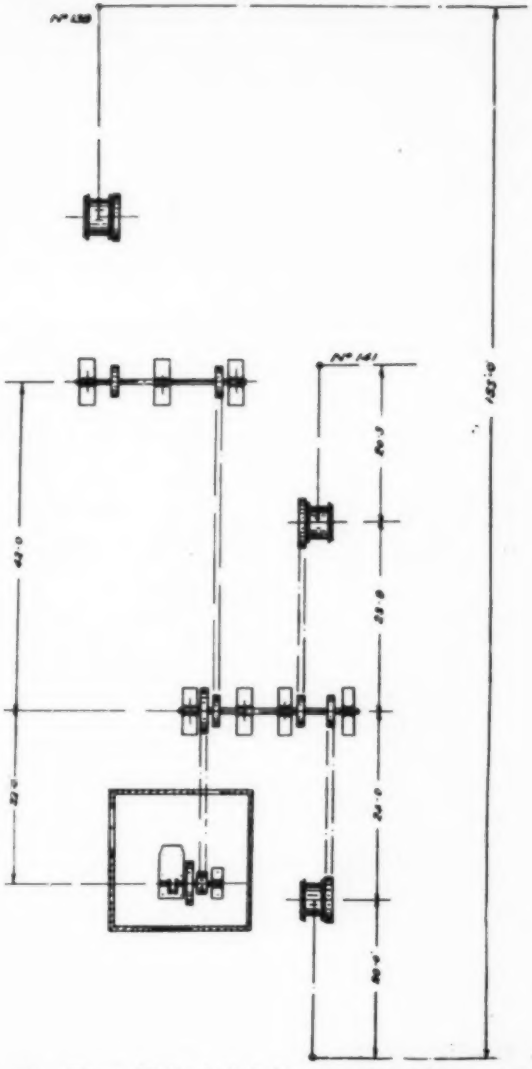


FIG. 17.—Three Wells bailed by one Oil Motor of 50 hp. (Ruston, Proctor & Co. Ltd.), using 14–15 poods of oil per day. (Vaspurakhan Plot, Baku Russian Petroleum Co.)

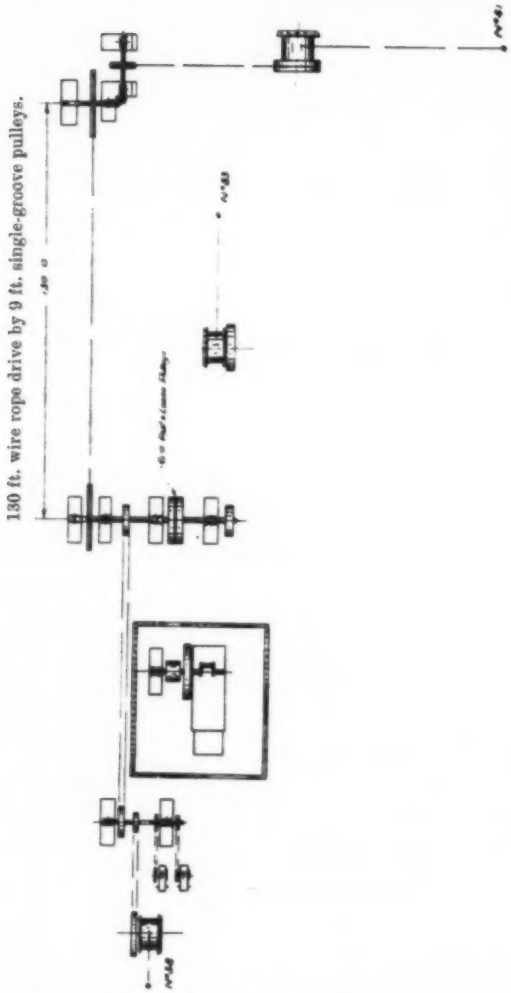


Fig. 18.—Hornsby Gas Engine of 150 hp. using well-gas, and bailing three wells with wire-rope transmission and bevelled cogs at right angle. Also works two 8 in. × 6 in. pumps raising the production of the plot (173, Baku Russian Petroleum Co.).

effected. Figs. 17—19 are illustrative of the transmission principle as applied to-day in actual practice.

Fig. 19 is of particular interest in shewing the difference between the power centralized, as in this case, and power by means of a motor installed at each well. It will be seen that one 150 H.P. motor, centralized, is sufficient to drive the four wells, whereas by installing a motor in each well about 200 H.P. would have had to be installed.

There is a great opportunity for introducing some more flexible type of power transmission, in order to make the application of electric power, or power by internal-combustion engine, commensurate with the great economy effected in fuel.

Attention should be paid to the standardization of the motors used on a particular property. If the required powers do not vary greatly, one type and power of engine should be used throughout. With varying powers, it may be found expedient to subdivide, and use two types of engine. In one word the plant should be standardized. This enables the minimum number of spares to be kept, and allows of rapid interchange of parts from one engine to another when necessary.

By installing oil-engines of the requisite power there is no reason why all classes of wells should not be drilled and eventually exploited by this form of power, so gaining the benefit of the great economy in fuel.

Where, however, a central electric supply exists, as for example in the Baku field, the tendency is rather to join wells on to that supply system, thus saving initial capital outlay.

But the oil-engine has created a large and important sphere of its own by facilitating profitable operation of a large class of wells, which, owing to their small yield, could not have been profitably exploited by steam or electricity. Such wells had formerly to be closed down, but, since the advent of the oil-engine with its low fuel-consumption, their operation has become possible. For outlying districts and for prospecting work the oil-engine is better adapted than any other form of power, more especially when water supply is limited. The Binagadi oil-field, an outlying district in the Apscheron Peninsula, without adequate water-supply, is worked almost entirely by means of the oil-engine. The new Ural and Biellik districts in Russia are largely worked by oil-engines.

Summing up therefore, as far as fuel economy is concerned, the oil-engine may be considered ideal. The defects of the system

as used at the present time are decentralization and want of flexibility in transmission of the power.

The next form of internal-combustion engine is that utilising gas, natural or artificial. Well-gas, formerly allowed to escape to waste, has of late years been collected and used as fuel, either for steam-raising purposes, or directly in the gas-engine. Thermo-dynamically it is, of course, burnt to greater advantage in the gas-engine. The gas-engine is simpler in construction and lighter than the oil-engine of corresponding power, and is therefore cheaper. The fuel, well-gas, has at present no commercial value,—which the oil used in the oil-engine has. In thus burning a waste product, the gas-engine costs nothing for fuel. A great point of advantage, possessed by the gas-engine over the oil-engine, is its greater flexibility. Under extreme circumstances it can be speeded up to 250 revolutions or reduced to 110, as exemplified in practice by a 45 h.p. Tangye engine when drilling a well lately on the Krimskaya oil-field in Russia. The stoppages for cleaning are less than with the oil-engine.

A drawback to the extended use of the gas-engine is the uncertainty of the supply of gas. It has therefore as a rule only been installed when the supply is more or less assured.

The economy of using waste gas, and the convenience in application of the power on account of the greater flexibility of the gas-engine, have led to the introduction of modified types of engines, arranged to use liquid fuel, should the supply of natural gas give out at any time. Two types of engine embodying this principle will be briefly described.

1*st Type.*—This engine runs as a gas-engine proper all the time. The one shown in Fig. 20 is manufactured by Messrs. Tangyes. Ordinarily the engine works on well-gas, and is in fact Messrs. Tangyes' oil-well gas-engine. In cases when the gas-supply is non-existent or inadequate, the engine is run on gas made from crude oil in a special vaporizer attached. This is heated by means of the exhaust gases from the engine itself. Of the crude oil admitted, about 40 % is vaporized and used in the engine. The engine must be initially heated by working it with some light oil like benzine. This engine has worked most successfully in actual practice, several deep wells to the writer's own knowledge having been drilled with this type of engine in the Krimskaya oil-field.

2*nd Type.*—This type is arranged to run as a gas-engine, or an oil-engine, as the case may be, by alteration of certain parts (Fig. 21). Particulars of this engine, manufactured by Messrs. Ruston, Proctor & Co., Ltd., were given in a valuable paper read by

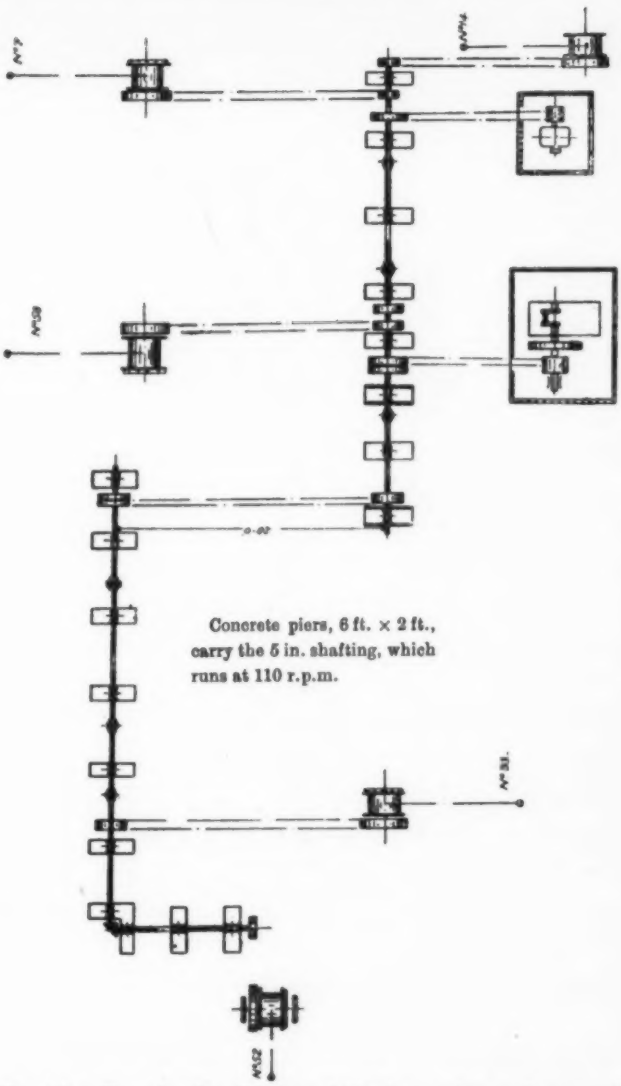


Fig. 19.—Hornsby Gas Engine of 150 hp., using well-gas, and bailing five wells with transmission by shafting. Electric motor in reserve. (Plot 175, European Oilfields Corporation, Ltd., Baku.)

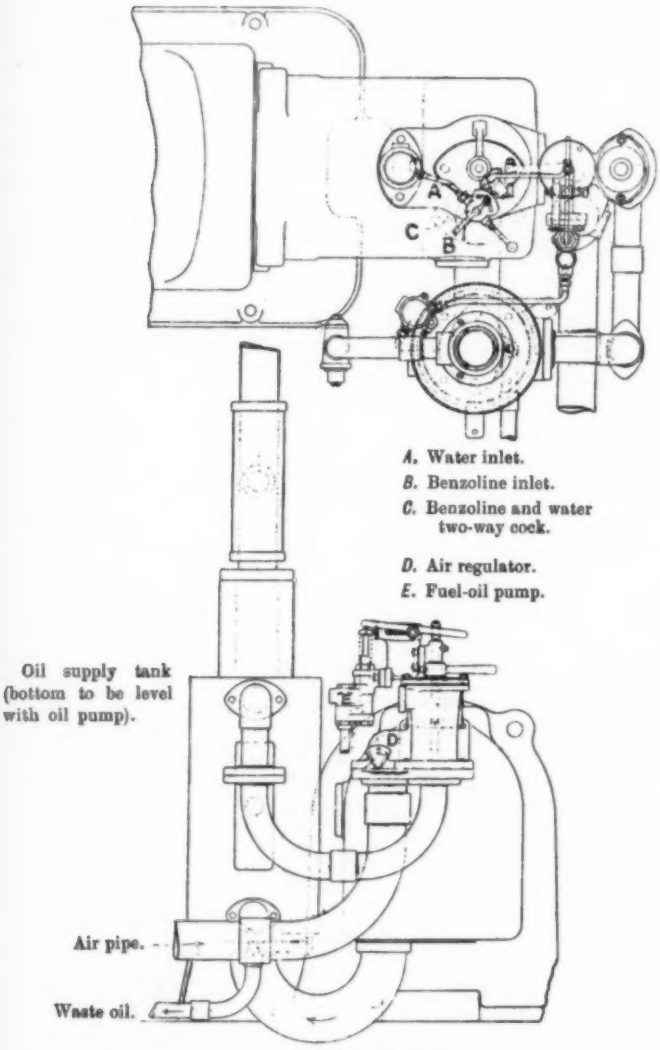
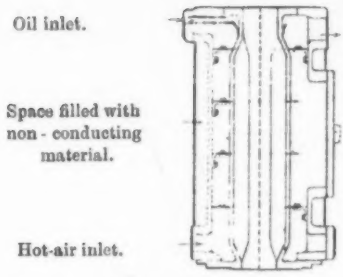


FIG. 20.—K S X Gas Engine, working with crude oil or benzoline



Section through vaporiser.
(Dotted lines are perforated plates.)

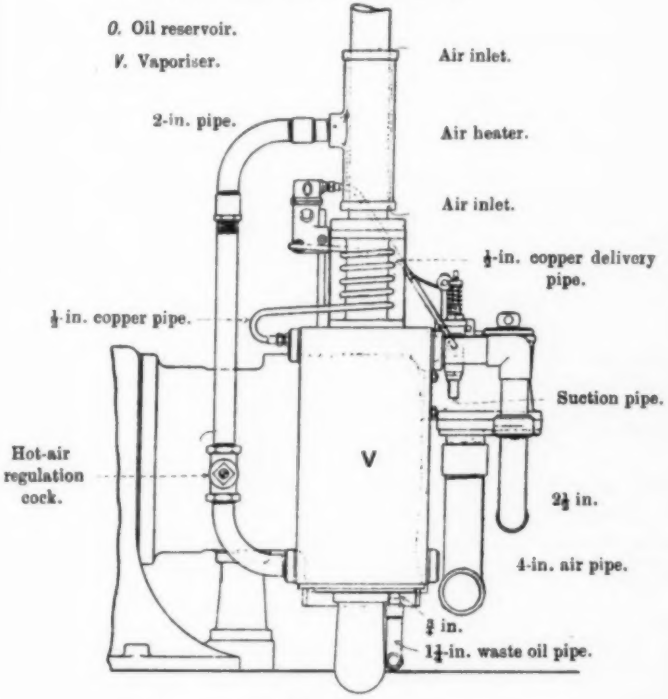


FIG. 20.—K S X Gas Engine, working with crude oil or benzoline.

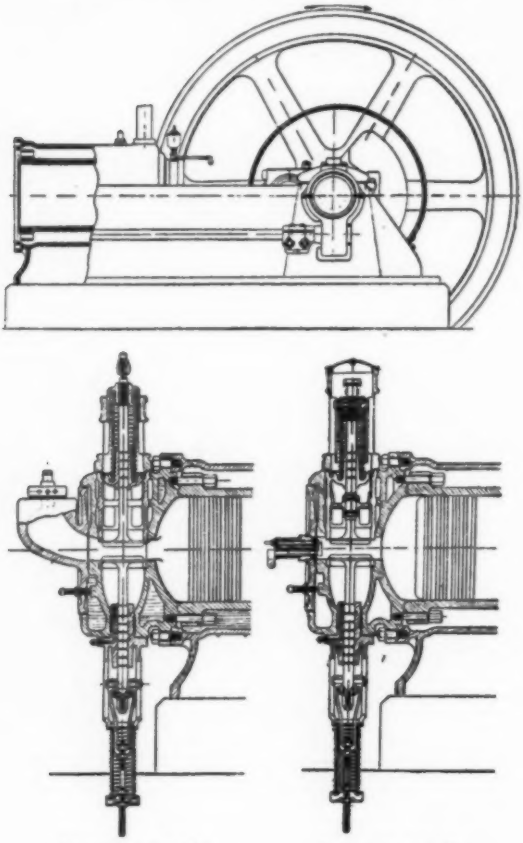


Fig. 21. Convertible Engine.

Reproduced by permission of the Institution of Mechanical Engineers.

Mr. A. E. L. Chorlton before the Institution of Mechanical Engineers last month. The author is indebted to that Institution for kind permission to reproduce the illustration, which shows the essential features of the engine, of which many are in successful operation on the Baku oil-field.

As described by Mr. Chorlton in his paper, these engines work with a higher compression for oil than for gas, involving some modification of the combustion chamber by substitution of a part for oil against a part for gas.

Thus the compression for the oil-engine is given at 250 to 280 lbs. per square inch, for the corresponding gas-engine at 150 lbs. Owing to the higher compression of the oil-engine, the efficiency is higher.

In this engine, to change from oil to gas, the following parts are necessary:

1. Piston for gas instead of piston for oil.
2. Combined air- and gas-valve.
3. Cover and sparking plug instead of vaporizer.
4. Magneto and gear.
5. Air and gas box for regulating mixtures instead of air-suction bend.

The extra cost in Russia for supplying the parts to allow the engine to work either as a gas- or an oil-engine is about £130. The time required to change from one type to another is about five hours.

It will be noticed that this convertible engine is essentially an oil-engine, and must be constructed as such with heavier scantlings than those of a gas-engine of corresponding power.

In deciding between an oil- or a gas-engine one would be guided by the question as to whether a gas-supply is available or otherwise: if available, a gas-engine would be installed from the start. If a gas-supply is not available at the moment, but is anticipated, one or other of the above types of engine working either on oil or gas might be recommended. In cases where no gas-supply is available or anticipated, one would instal the oil-engine from the start.

The types of internal-combustion engine made by manufacturers are very numerous, and it is not the purpose of this paper to examine them in detail.

It is a matter of some regret that, in the keen competition between British and German manufacturers, the old type of a slow-running, and therefore heavier, engine should have been sacrificed. Anything which tends to easy running for long periods is advantageous on an oil-field, and a slow-running engine is therefore preferable to one of high-speed.

In this striving for reduction of weight, the width of bearings have in some cases been so reduced that the engine will stand the running speed with the best white metal only, and such white metal is not always obtainable in the out-of-the-way places where those engines work. There is no doubt that better-class firms will readily pay more for the type of engine which will run for longer periods between stoppages for adjustment of bearings.

It should be of interest to manufacturers to know that a market was captured, and held for a considerable time, by one firm whose product was no better or cheaper than several others, but which had the reputation, locally, of running more satisfactorily. This reputation was largely gained by the firm's happy choice of a competent man, who watched the erection of each engine, assisted in its starting, and for years after would periodically inspect its running, and by his expert knowledge avoid anticipated trouble by either personally adjusting the engine or suggesting means of so doing.

Relative costs of producing the different forms of power, at varying fuel prices are given in Table III. These have been prepared from actual costs and estimates as obtained in practice in the Baku oil-field. Fuel, labour and supervision, depreciation and interest on capital have been taken into account.

Summary of Advantages and Defects of Different Forms of Power.

Steam Engine.—Low thermal efficiency, hence uneconomical in production of power. In its application at the point of use, highly flexible and sensitive, and hence ideal for oil-well requirements, in boring, baling and pumping.

Electric Power.—Higher thermal and general efficiency than steam-power owing to centralization. Possibly of yet higher efficiency in the use of the high-compression oil-engine. Unsatisfactory in its application from the constant speed of the transmitting motors, therefore not flexible, nor sensitive to changes of power required. Only adaptable on a large scale, and hence only suitable for proven fields of large extent.

Oil-Engine.—High thermal efficiency, ideal from an economical point of view. The same disadvantages as in the case of electric power, due to constant motor speed; viz., want of flexibility in transmission. Additional disadvantage of decentralization of the power plant. Adaptable in all stages of oil-field development.

Gas-Engine.—In addition to the high thermal efficiency as an

TABLE III. RELATIVE COSTS OF DIFFERENT FORMS OF POWER IN BAKU.

Price of Fuel in Copecks per Pood.	Steam Power.	Electric Power Generated for own requirements.	Electric Power Company, Ordinary Tariff.	Electric Power Company, Preferential Tariff (over 8 million kw. hours per annum).	Oil Engine Power.
20	5·44	2·96	3·70	3·51	2·20
21	5·64	3·01	3·78	3·51	2·22
22	5·85	3·06	3·86	3·51	2·25
23	6·06	3·11	3·94	3·51	2·28
24	6·27	3·16	4·02	3·51	2·31
25	6·48	3·21	4·10	3·51	2·34
26	6·69	3·26	4·18	3·70	2·36
27	6·90	3·31	4·26	3·70	2·39
28	7·11	3·36	4·34	3·70	2·42
29	7·32	3·41	4·42	3·70	2·45
30	7·53	3·46	4·50	3·70	2·48
31	7·73	3·51	4·58	3·88	2·50
32	7·94	3·56	4·66	3·88	2·53
33	8·15	3·61	4·74	3·88	2·56
34	8·36	3·66	4·82	3·88	2·59
35	8·57	3·71	4·90	3·88	2·62
36	8·77	3·76	4·98	4·07	2·64
37	8·98	3·81	5·06	4·07	2·67
38	9·19	3·86	5·14	4·07	2·70
39	9·40	3·91	5·22	4·07	2·73
40	9·61	3·96	5·30	4·07	2·75

internal-combustion engine, is particularly economical in oil-fields, on account of burning a waste product. Can use oil as fuel directly by conversion into gas by outside means, with an increased consumption. More flexible and sensitive to required changes in power than the oil-engine. Also lighter and less complicated.

Quicker starting and restarting. An ideal engine for the oil-field, especially for the higher powers.

In conclusion, the author desires to express his acknowledgment to Messrs. A. F. Dabell, John Walton, John Bolton and K. Watts for kind help in making suggestions and drawing figures for this paper, and to the firms of Tangyes, Ltd., Ruston, Proctor & Co., Ltd., R. Hornsby & Sons, Ltd., and Crossley Bros., Ltd., for information supplied regarding their engines.

DISCUSSION.

The President said that, having regard to the extent to which the internal-combustion engine was replacing the steam-engine as a source of power for general purposes, he thought it might be confidently anticipated that in the oil-field the oil-engine would be still more largely used than it had been shown to be in the paper. All the members would agree that the author had stated the case clearly and dispassionately. He had illustrated the respective advantages and disadvantages of the three sources of power with which the paper dealt, and he thought most of those present would have gathered the impression that, where circumstances permitted, the electric system had such great advantages over the others that it was likely to be the one selected, but, as the author had pointed out, the electrical system could only be advantageously employed in oil-fields which had reached an advanced stage of development. There were numerous illustrations of the effective manner in which electricity could be so employed, not only in Russia, with which region the paper chiefly dealt, but also in Rumania. But, for isolated sources of power, it was obvious from what the author had stated that the choice must lie between the internal-combustion engine and the steam-engine. Personally he was brought up with the steam-engine, and had learned to love it. It was long-suffering, to such an extent that engines of this type were often seen laboriously doing duty in a condition of decrepitude which was almost pathetic; and he thought that the capacity for work under disadvantageous conditions was at least as important as the capacity, to which the author had alluded, of dealing with an overload. There was no doubt that in many cases a steam-engine, even in an exceedingly bad condition, was a better servant than a gas-engine or an oil-engine of nominally equal power. The oil-engine was comparatively fastidious, and unless it was kept in a state of high efficiency no

work could be got out of it. He remembered many years ago hearing, in the room in which the present meeting was being held, the late Sir Frederick Bramwell state that before long it would only be possible to find a steam-engine in our museums, but that statement was made before the advent of the turbine engine gave steam a new lease of life. Turning to the internal-combustion engine, and referring to the defect alluded to by the author, that there was a rigid limitation of the power which could be got out of it, he ventured to suggest that the analogy of the road motor vehicle would lead them to think that the defect might perhaps be most simply met by the employment of suitable variable-speed gear.

Mr. W. Calder thought the paper was of great importance to oil engineers in laying out the plant required for the development of proven oil properties, and that it would be of great interest to all engineers engaged in the industry. So far as the steam-engine was concerned, it was a type of plant which permitted of being gradually built up as development proceeded, which was not possible with other types of plant. It also had to be borne in mind that operators would not spend the amount of money that was necessary for the erection of a big installation.

The steam-engine was also, as the author had stated, very flexible for drilling purposes. Variations in the strata suddenly occurred, and the driller must at once alter the speed of the engine. That could not be done with a motor, but with a steam-engine it could be done instantaneously from the floor of the derrick. A motor required concrete foundations, which could not be put in immediately, whereas a steam-engine could be moved about quickly, and it was a plant which was very suitable for exploration-work, as the requisite fuel and water could usually be obtained.

The author had stated that the standardisation of motors was very essential. This applied not only to motors but with regard to all other plant on oil-fields. On most fields all sorts and sizes of plant of different makes were to be found, and when a new man arrived to take charge, the first thing with which he had to concern himself was to find out what could be done with the plant on the spot, ordered by various predecessors. He had to contrive ways and means of utilising the assortment of makes, accidents naturally resulted, and he was blamed for the work going wrong, and told that he did not come up to expectations. Another engineer would be sent in his place who would immediately be faced by the same problem.

This was true not only of motors but steam-engines, drilling-plant, and everything used on an oil-field. Why should such a state of things continue to exist? Was it not possible to have some standardisation in the oil industry as in other industries? Was it fair to expect a man who was sent away to some out-of-the-way hole on the other side of the world to tackle a difficult job with plant impossible to combine satisfactorily for practical use?

With regard to the question of the use of the gas-engine, the Tangye gas-engine was a very suitable one for oil-field work, requiring only a very small amount of gas. As long as there was oil worth extracting on an oil-field, it was his experience that sufficient gas would be found for the gas plant.

Electric, oil, and gas motors were quite suitable for drilling purposes down to depths of about 1000 ft., but below that depth the weights of casing which had to be moved were much too heavy for the fast and constant speed of all classes of motors. When the casing stuck, it was necessary for the driller to put on a heavy and steady strain, impossible with the motor, as its power cannot be applied gradually. When used for freeing casing or tools, it effected a series of sudden jerks, which frequently broke the derrick, an accident which, on an isolated field, might mean a three-months stoppage before the derrick could be again in use. That was the way in which oil-fields were lost. As the author had pointed out, the power from the steam-engine was so flexible that it could be increased or decreased every second or as required, and this permitted the quiet easing up of stuck casing or lost tools, without any undue strain on any part of the drilling plant.

The author had briefly referred to the use of compressed air. Personally he thought internal-combustion motors of large hp. could be used advantageously and economically with compressors in central stations, and that compressed air would probably be found the most suitable for oil-field work, its present known disadvantages being of such a nature as to present no difficulty to the engineer. The steam-pipe lines now in use could be used for low-pressure compressed air, and considering the many advantages which a combination of motor and compressor presents, he thought it would eventually be found the cheapest method for the purpose of generating power centrally.

Everyone who had had any experience abroad would admit that, once an English manufacturer sold a motor or whatever it was, he thought his part of the business was finished. This was not so; it was necessary to bear in mind that the plant sold is

frequently placed in the hands of men who in all likelihood have never previously seen that particular make of machine or tool, and for this reason may not give it the special care necessary for good work. Motors, more than any other class of machinery, required special attention wherever they were worked.

It was the general experience that the class of labour available on oil-fields as motor attendants was not high. It generally consisted of men which had drifted into the district on the chance of getting a job, and as they found it was a good-paying business, they stopped there and gradually worked their way up. They perhaps started as labourers, and eventually became head mechanics, because they had shown special ability in certain work. The majority of the men in Baku were trained locally, and their experience was confined to the machinery in use there. As a result, when plant of a new design was introduced, it was frequently condemned before a wheel had turned. A few years ago, if anyone went with a new idea to Baku, he could not get it tried at all; being new, most of the people on the spot had never seen or heard of it, and for that reason condemned it.

Manufacturers should therefore keep in touch with the purchasers of their machines and tools; by doing so, they would appreciate why their goods are frequently condemned, and the reason of their receiving no repeat orders. Another point is that besides their selling agents, they should have experienced resident engineers, who, not only could advise purchasers respecting upkeep of plant, but also would give the manufacturers ideas respecting the class of service or duty expected.

Mr. E. W. Petter, speaking as a manufacturer, desired to say, in the first place, how very much indebted he felt to the author for his very interesting and instructive paper, which would be a most useful work of reference. The paper dealt with two totally different problems, namely, the comparison of the various powers mentioned when considered as separate units, and the question of the application of power through a central station. As an oil-engine manufacturer, he was glad to notice that the results obtained, at any rate from the consumption point of view, were very much in favour of the oil-engine. If he might be forgiven for saying so, he thought the introduction of the electric drive was a little outside the scope of the paper, because it was not a prime mover in itself, but simply a different means of application of the power used.

He desired to deal with one point on which the author had

laid emphasis, namely, the inflexibility of the oil-engine, because he did not think the oil-engine, particularly of the semi-Diesel or high-compression type, was so inflexible as the author supposed. The author referred to a variation of 2½ % above, and 5 % below, the normal speed as being a very remarkable thing in an oil-engine. He thought his brother manufacturers would agree with him that such was not the case. A modern oil-engine, particularly of the high-compression type, lent itself to a considerable range of speed. It was the common practice to govern a high-compression oil-engine by regulating the stroke of the fuel injection pump, and by adopting that method it could be governed down from a normal speed almost to any extent by shortening the stroke of the pump. The governor could be adjusted to control the engine at the normal speed, and then by the simple device of shortening the stroke of the pump, and taking the engine off the governor, the speed could be reduced as desired, in fact controlled in exactly the same way as a motor-car engine was controlled.

As the author had very kindly sent him an advance copy of the paper, he had had the opportunity of making some tests on an engine of the type described, the results of which would, he thought, prove interesting. An engine of 40 normal hp., running at 300 revolutions per minute, with a consumption of 0·472 lb. per B.H.P. per hour, was slowed down in the manner described, by shortening the stroke of the pump to 214 revolutions per minute, a B.H.P. then being obtained of 29·1 with a consumption of 0·487 lb. per B.H.P. per hour. The engine worked quite regularly at the reduced speed with regular explosions, and although the means on this particular engine did not admit of further reduction, there was no doubt the speed could have been further reduced with equally good results. The method of effecting the reduction was extremely simple, and could be operated at any distance from the engine. The effect upon the engine was instantaneous, and the operator could control it to any desired speed from the fixed maximum to something under one-half the maximum. The operation is in fact similar to that of the decelerator which is commonly used on several well-known makes of French motor-cars. Some objection might be taken to the cutting out of the governor, but there was really nothing in it, because the control could be brought quite easily to the derrick, and the attendant would control the engine instantaneously in exactly the same way as he did in a steam-engine. The author had suggested that it was more difficult to make an addition to the amount of power with oil-engines than it was with steam-engines. He presumed

therefore that the steam-engines used in small units were always portable units, and if that was the case he could quite understand that additions were easily made, but if not, he did not think there was any more difficulty in adding oil-engines than steam, in fact he believed oil-engines could be added as easily, if not more easily, than steam, when the addition of boilers, pipes and everything else was taken into consideration.

Mr. Horace Wyatt said that, although he had no personal experience of work upon oil-fields, he desired to point out that there seemed to him to have been a certain amount of confusion in the paper between the original source of power and the means of transmitting that power to do its work. The author had referred to steam, electricity, oil and gas as if they were all original sources of power. Electricity was obviously not an original source; it was merely generated as a result of employing one of the other three. That seemed to him naturally to connect itself up with the remark the President had made to the effect that the question of the transmission, after the oil- or the gas-engine had been employed, appeared not to have been sufficiently studied up to the present moment. Speaking from the point of view of one whose business took him mainly amongst motor-cars, the transmission, even in the case of small installations, need not necessarily be mechanical, but might be electric, which brought them back direct to the question of the central station depending for its power upon oil or gas; or, looking at the subject from a smaller point of view, to what corresponded to the petrol-electric vehicle in motor-car practice. An oil- or gas-engine and an electric transmission, which was exceedingly flexible, could be put into the space available on the chassis of a motor-omnibus, and there were hundreds of them running in London at the present moment.

It seemed to him there was something to be done, or at any rate to be thought about, in the way of the erection of an oil-electric installation, not necessarily on the scale of a central station, but rather on that of the petrol-electric omnibus. Certainly there were possibilities in connection with such a scheme. Reverting to his own particular line of business, there were, broadly speaking, two kinds of petrol-electric transmission, in the first of which the engine was used direct to drive the dynamo which generated the current to supply the electric motor; while in the second an electric battery was also included in the system to act as a kind of buffer or reservoir to keep the supply steady. It appeared to him that there were great possibilities, as a result of the enormous

improvements which had been made in electric batteries during the last few years, of using these as equalisers of power on comparatively small installations. He was not referring to installations on a large scale, which were justified when an oil-field had been thoroughly developed, because admittedly a central station was probably the most economical arrangement when work on a large scale had to be carried out. It seemed to him, however, that, worked on a small scale, there were great possibilities in the use of internal-combustion engines, coupled with some kind of electric transmission, possibly with a battery interposed as a kind of reservoir.

The following communication from **Mr. J. Wells,** who was unable to attend the Meeting, was read by the Acting Secretary :—

Mr. Rappoport has introduced a subject which is not only of immense interest to every member of the profession, but a matter of very practical importance in regard to the cost of drilling operations as a whole.

Apart altogether from the development of electricity on large scale operations, there is undoubtedly a vast field for enterprise in the adaptation of the internal-combustion engine to drilling, but the lack of flexibility in the heavy, slow-speed, internal-combustion engine, whether of the Diesel, semi-Diesel or light-oil types, is a matter which is a grave defect, more especially for that delicate control which is an essential feature in a number of the manipulations necessary throughout the twenty-four hours of the day.

Very naturally the development of the oil-engine has been followed in Russia with perhaps more interest than in any other field, and its adaptation has been largely possible with the cumbersome machinery employed, and the peculiar circumstances of local conditions.

The greatest defect, perhaps, that has to be faced is the lack of skilled labour, which, however, appears to be by no means common to Russian fields, and I think that this lack of skilled labour is perhaps the greatest deterrent to the use of internal-combustion engines.

I was inclined to agree with Mr. Rappoport as to the advantages of the heavy type, slow-speed engines of large cylinder capacity at slow speed, but, on the other hand, this type of engine has innumerable disadvantages, amongst which may be cited its great weight and its heavy single impulse, the power of which must of necessity be absorbed in a sufficiently heavy fly-wheel, and, again

the immense difficulties in the way of provision of any considerable variation in speed.

If we turn to the multiple cylinder engine, such as has now become common practice in marine work, we have undoubtedly better circumstances as regards speed-variation, together with a not unsatisfactory torque, and, further, within wide limits of speed-variation, by means of a suitable reduction-gear between the high-speed engine unit and the countershaft of the drilling rig, we may greatly enhance the value of our speed-variations, and also maintain a high torque effect. As against these advantages we have to consider the disadvantage of the necessity of comparatively highly skilled labour. I very much doubt if this is a disadvantage.

Given that there are certain advantages in the multi-cylinder, high-speed engine, the question of absorption of the fly-wheel energy in the initial pick-up in putting the drilling rig into motion is quite satisfactorily overcome by the use of metal-to-metal clutches of, for example, the David Bridges type. With these clutches the pick-up can be as gentle as anybody could desire, or can be fierce enough to break almost anything. Such a clutch will cost in the first instance two or three times the belt of equivalent power, but its life will be from 5 to 10 times that of any belt, and even then a few pounds spent in renewals will provide a clutch almost as good as new.

Coming now to the question of intermediaries between prime mover in the form of an oil-engine and the drilling rig, we have a variety of choice, namely, electricity, compressed air, and hydraulics.

With regard to the first I do not feel competent to discuss it.

With regard to the second, we are dealing with a medium the limitations and economy of which are thoroughly well-known and exemplified from ¼ hp. units up to units of many thousands of hp.

Mr. Rappoport has drawn particular attention to the objection to a large number of individual isolated units, that is, a separate oil-engine to each rig; but a small central compressor house appears to me to be a method of getting over many of the disadvantages in a manner economical, practical and in accord with the requirements of the intellectual ability of the average rig hand.

If we take a small-scale station with initial pressure of, say, 55 to 60 lb. to the square inch, we may economically deliver this within a 1,500 ft. radius in proper-sized pipes with a terminal loss of not more than 3 or 4 lb., and assuming that we are using the air without any re-heating, we may reasonably expect to obtain

an average overall efficiency of 45 to 50 %, that is to say, if the fuel economy of the oil-engine over the ordinary steam unit is, say, 5 : 1 in favour of the oil-engine, we shall have improved matters in the proportion of $2\frac{1}{2}$: 1. This is a very considerable economy, and though perhaps not ideal, is a step in the right direction. However, there is always the question of climatic circumstances to consider, and in extremely cold climates there would undoubtedly be difficulties with freezing of exhausts.

The failure of small compressed-air units is mostly attributable to the lack of sufficient receiver-capacity. Receiver-capacity is an essential feature to meet the peak loads, and often on large air-installations one finds this fundamental error in the general arrangement of the plant.

We pass on now to the question of hydraulics, and we have here a more or less ideal power for pumping and for rotary drilling rigs. For many years vast energies have been expended by engineers the world over to obtain a really satisfactory means of hydraulic transmission with a suitable rotary engine. Among the various attempts which have gone some way towards success, I would mention specifically the efforts of Pitler, Lenz and Hele-Shaw. The best of these is undoubtedly the Hele-Shaw, wherein the prime mover of constant speed is coupled to a pump running at a constant speed, but with provision for variable volume-output, delivering oil under pressure to a constant-volume motor, but variable in speed through the pump. The main advantage of this combination is that the pressures are directly proportional to the work being done, coupled with the fact that the torque or turning effort is the same at all speeds for a given pressure. The motor through the pump is instantly reversible, and the control is such as permits either an extremely fierce, or the most gentle, application of power, in fact, a control so far ahead of that possible with any steam-engine that it has to be seen to be believed or appreciated.

However, wherever the question of intermediary between prime mover and the machine to be driven comes in, there is the question of cost, and although one comes across exceptions in the profession, I think as a whole the profession is obsessed with the fetish-cult of cheap plant. One may certainly overdo the cost of plant, but the quality of material and quality of machinery accepted on many drilling propositions is undoubtedly the road to ruin.

In conclusion, I must apologise for taking up so much of your time, but there is one other item of development, but which so far has not arrived at a practical stage, namely, the application

of the internal-combustion engine in combination with the injection of water. I have seen one or two experimental engines which promise well for the future, but are yet in the embryonic stage, in which, however, there is a flexibility almost equal to that of the steam-engine.

Mr. F. G. Rappoport, in reply, after thanking the members for the very kind way in which they had received his paper, said the President had referred to the question of the application of variable speed gears in order to obtain the necessary change of speed. The only way by which at present this had been obtained on the oil-fields was by means of a pulley transmission-gear between the motor and the boring rigs. The obvious disadvantage of that method was that the speed could not be changed instantaneously; it involved a somewhat lengthy process of changing pulleys, and was not a convenient method. In those cases where it was possible for time to be allowed for changes of speed to be made, that was certainly a method which could be, and was, adopted. The important point to be borne in mind was that, in adapting the internal-combustion engine to oil-field conditions, it was necessary for the engineer to take what he found on the spot. There were the boring rigs, and the baling drums, and to adapt some variable means of transmission to those machines was extremely difficult. If the work could be started all over again, and the rigs rebuilt, no doubt something could be done, but at present the only method by which a variation of speed could be adopted, was, as stated, by means of transmission placed between the engine and the rig.

He quite agreed with the Chairman's remarks with regard to the steam-engine and its long-suffering capabilities. The difficulties experienced in the early days of the introduction of oil-engines were considerable, as at that time the oil-engine had not been brought to the perfection to which it had at present attained. It was through the experience obtained from the working of oil-engines that they had been made the more or less perfect engines they were at the present day for oil-field use. As Mr. Calder had pointed out, the questions of fuel and water had particularly to be borne in mind in connection with the use of oil-engines. Very often, especially when prospecting in outlying districts, water could not be obtained in sufficient quantities for even portable steam-plants, and that was where the oil-engine displayed its great superiority, in its convenience and economy. On the other hand the question of fuel might militate against the use of the

oil-engine for prospecting purposes, because it was not always possible to obtain a supply of oil-fuel, even in the small quantities required by the oil-engine. In those circumstances a portable steam-engine using timber or coal-fuel, whichever was the more convenient to be obtained, would have to be used.

He had laid great stress on the necessity of standardisation. Some engineers liked to calculate out the exact horse-power which each well required, and install the motors accordingly. It might, for example, be found that one well required 40 hp., another well 50 hp. It would not be good engineering practice to install two such motors in different wells. The 50 hp. motor should be installed in each well, thus effecting standardization. A well producing large quantities of oil might be stopped by breakdown of the motor, whereas one which was giving a smaller quantity of oil, and which was therefore not so important, was working. Under these circumstances, the part of the machinery which had broken down on the larger-producing well could be replaced by parts of the motor from the smaller, so that it was possible for the more valuable well to continue working.

It would probably be of interest to the members, if he stated that the normal consumption of gas, of a calorific value of about 7,000 calories, was about 13 or 14 cubic feet per B.H.P. per hour.

The question of the seizing of the casing was one of the most important cases in field practice, and one which demanded a type of motor capable of gradually applying an increasing power until the highest limit was reached.

Several speakers had mentioned the question of the use of compressed air. That was a very big subject, which he had merely alluded to in the paper because he thought it should be touched upon. It was interesting to know that two of the first oil-engines which were sent out to the Baku oil-fields by Messrs. Hornsby were supplied for the purpose of trying the use of compressed air as a means of power. Experiments were conducted which lasted well over six months, and although they were eventually abandoned, he considered they produced good results, as they clearly proved that compressed air could be used with advantage in properly-constructed engines. It was unfortunate that the state of the well-engines in use at that time did not allow those particular experiments to be entirely successful. One of the difficulties experienced was the freezing of the exhaust ports, due to the expansion of the compressed air. It was found that reheating was absolutely necessary, the pressure of the compressed air not being sufficient to dispense with reheating. This, however, was

almost an impossibility on an oil-field, where it was quite out of the question to have an open flame anywhere near the derricks. Centralized air-compressing plant, using high-pressure air in properly-designed engines at the well would probably solve the difficulty, and he had no doubt the day would come when compressed air as a means of power on the oil-field would be resuscitated, as stated by Mr. Calder. That was the time when the oil-engine would again assert its claims in producing this power. The economy of the oil-engine could thus be combined with the flexibility which the use of compressed air gave, and the power supplied with the minimum loss of transmission between the point where the compressed air was produced and the point where it was used.

The question of the purchase of oil motors, to which reference had been made, was interesting. Many purchasers were not engineers, and had no idea about oil-engines, or engines of any sort. All they wanted was the cheapest form of power,—the payment of least number of pounds sterling per hp. They knew nothing about piston speed, and it did not matter to them whether the engine was slow or fast running; but at the same time they were the first people to complain if anything went wrong on account of the high speed at which the engine ran. He had been very much interested in Mr. Petter's remarks regarding the flexibility of the oil-engine. The whole point which he (the author) wished to make was that there was not, in the case of the oil-engine, the instantaneous response to the varying speeds frequently required in oil-field operations that there was in the case of the steam-engine. The trials described by Mr. Petter certainly suggested that it was possible to obtain greater speed-variation with oil-engines, and therefore greater flexibility, than he (Mr. Rappoport) had thought possible.

The steam-engines used on an oil-field were not portable as a rule, portable steam-engines being used only in the early prospecting stages. The installation of a steam-engine itself at the well was on a considerably smaller scale than that of an oil-engine. The difficulty connected with the use of oil-engines was that a very expensive plant was installed at each well, that fires were of common occurrence at oil-fields, and there was thus a great chance of losing this expensive plant from that cause. In a boiler house, or a central electric station, the plant was centralized, and it was safe as a rule.

The point Mr. Wyatt had alluded to was of much interest. It must be borne in mind, however, that it was necessary to have

simplicity on an oil-field, and to have as little plant as possible in the derrick, owing to the danger of damage from fire and other causes. While the introduction of an equaliser such as Mr. Wyatt mentioned might probably be tried, it would naturally complicate the plant, and it would be difficult to adopt such an arrangement for changes of speed on existing plants. The plant used was of considerable size, and it would require a great deal of thinking out before such an arrangement could be adopted in the manner practicable in the case of the internal-combustion engine used on motor-cars. The marine type of motor would probably eventually be adopted, as it was the most flexible, but at the present time the units supplied on oil-fields were of the single-cylinder type, very few double-cylinder types of engines having been supplied.

He had been much pleased that Mr. Wells had mentioned the Hele-Shaw system of power-transmission, and he hoped that gentleman would give his views, *in extenso*, in a subsequent paper on the subject. He had had occasion to see the system working successfully on a motor-car, and he understood that one or two English firms were seriously thinking of applying it on the oil-fields. It would be a particularly flexible method of transmitting power. He was afraid he was not capable of explaining it, but it was a patent well worth the consideration of all oil engineers.

On the motion of THE PRESIDENT, a cordial vote of thanks was passed by acclamation to Mr. Rappoport for his most interesting and valuable paper, and the meeting terminated.

Mr. M. A. Ockenden subsequently sent the subjoined note:

A new drilling gas-engine, known as the "Black Bear," has been in operation for the last two years in the Californian oil-fields, and has given satisfaction. The B.T.U. in the gas of the different fields varies greatly, and the engine is therefore conservatively rated as 35 B.H.P., but with good gas this rating is greatly exceeded.

This engine is designed with a view of meeting the severe requirements of the oil-fields. It is of 4-cycle type, with valve-mechanism, operated by a cam shaft driven by spiral gears from the main shaft.

The speed of the engine can be controlled by a line operated from the derrick-floor when the engine is being used to pull tubing or tools, as the regulation is effected by a Pickering governor, which can be set to operate the engine at a fixed speed, if desired. The normal speed of the engine is 135 r. p. m. The speed of the

pulley on the reverse gear, when reversed, is 350 r. p. m. which gives a much desired effect, as the high speed can be used when pulling tubing or tools out of the hole.

Three forms of ignition can be utilized, either magneto and jump spark, hot tube, or make-and-break.

The engine is built with a short crank-shaft. On the pulley side there is a flange built as part of the fly-wheel hub. To this flange is bolted a short shaft, carrying either a regular clutch or a reversing clutch.

This engine is now being sold in the American oil-fields for drilling and pumping, and it is anticipated that it will soon be in general use in the oil-fields throughout the world where natural gas is available, especially where suitable water-supply for boilers is a serious problem.

M. A. O.

Mr. Rappoport replied as follows:

I am much interested in Mr. Ockenden's description of the "Black Bear" gas-engine, and have no doubt that, when more widely used, it will give the same satisfaction that it has given on the Californian Oilfields.

It will however be remembered that I stated, in my paper, that the gas-engine was considerably more flexible in its adaptability to varying loads, and in speed-regulation, than the corresponding oil-engine. A supply of gas is not always immediately obtainable, especially in new districts, when the question resolves itself into one of choosing between the steam-engine, with its great flexibility but high fuel-consumption, and the oil-engine, with limited flexibility but economical use of fuel. The evolution of the "convertible" engine is a direct result of the known greater flexibility of the gas-engine.

F. G. R.

Sixth General Meeting.

A Meeting of the Institution of Petroleum Technologists was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C., on Friday, 30th April, 1915, Sir Boverton Redwood, Bart., D.Sc., F.R.S.E., President, in the Chair.

The Members of Council present were Dr. F. M. Perkin, Messrs. E. R. Blundstone, T. C. Palmer and Arthur W. Eastlake. Prof. Cadman telegraphed regret for unavoidable absence.

The President, in opening the Meeting, said he very much regretted to have to announce the death of one of the most highly respected Members of the Institution, Mr. John D. Campbell, which occurred at Lobitos last Good Friday. Many of the Members knew the value of the work which Mr. Campbell had done in the development of the oilfields of Peru. The success of the Company known as Lobitos Oilfields, of which he was the General Manager at the time of his death, was mainly due to his services, and his death created a gap which it would be found extremely difficult to fill.

The following paper, illustrated by lantern slides, was then read :—

Oil-well Engineering.

By William Calder, M.Inst.M.E. (*Member*).

Introductory.—The Drilling of Deep Wells. The blind speculation which formerly prevailed in most mining ventures, has, by means of well-drilling machinery, been reduced to a minimum, and there should no longer be any doubts as to the true value of any mining property, as this can be exactly ascertained at a minimum cost before any expenditure of capital has been made on shaft sinking and general equipment.

It is, consequently, only within the last 20 years that deep-well, or borehole drilling, has come to be recognised as a separate and important branch of mining engineering. So important of late years has this industry become all over the world in the search for water, oil, brine and other minerals, that its direction has really become a profession apart from that of mining, and one that merits even fuller appreciation than it receives at the present time.

As most branches of mining are very much overcrowded, the

young engineer of to-day has undoubtedly a difficulty in deciding which branch to adopt, and it is suggested that serious consideration be given to deep-well engineering, as being less crowded and proffering much better remuneration than can be obtained in other branches of mining.

It should however be noted by all intending to take up this calling, that before they can hope to occupy any responsible position, they must thoroughly prepare themselves for the work, and therefore, besides a good knowledge of general mining and mechanical engineering, a course of practical well-drilling work is absolutely essential. Such a course should be extended over a period of not less than two years, and should include both the rotary and percussive systems of drilling.

The occasion is opportune to point out that the work is very arduous, and none but those of strong constitutions should engage in it, also that as the localities of deep wells are often isolated, and frequently far removed from centres of civilisation, the engineer taking up this class of work must be prepared to forego many of the comforts and pleasures which are to be found in civilised places.

Unlike other classes of mining, in which the need of deep wells is only essential in prospecting to give data as to strata, mineral values and depths, the search for and exploitation of petroleum depends solely on deep wells, and engineers in charge of such work must be so thoroughly acquainted with all details of well drilling, that it is only by having undergone a thorough practical training that anyone can hope to be successful.

Drilling a small hole into the bowels of the earth may appear very easy to the layman, but it should not be forgotten that all the work is out of sight, and furthermore confined to a very small hole, thus demanding greater experience, ingenuity and patience, than is required in other branches of engineering, where the work can be examined by eye.

The difficulties encountered in passing through the varying strata are enormous, and often very hard to overcome, whilst, owing to the differences in detailed structure, it is seldom that two wells are similar in respect to these difficulties, wells drilled close to one another frequently presenting dissimilarities incredible except to those actually in charge of the work, especially where the strata have been faulted and broken up, or otherwise present more than the normal irregularities.

From the foregoing remarks, it will be realised how important it is, that all connected with the work should have had thorough

practical experience, in order to be able, not only to judge when tools are working to the best advantage, but also (which is of yet greater importance) when accidents occur, to realise instantly the exact nature of the accident, and promptly to take the necessary steps to overcome the particular difficulty.

The vast majority of accidents which take place are undoubtedly caused by the inexperience or carelessness of the drillers, inexperienced men, more frequently than not, being engaged at times when there is a scarcity of competent labour. Such men, however, are soon discovered by the engineer in charge, provided he has had the necessary training.

Careless drillers are, if anything, worse than men entirely without experience, and should not be employed in any responsible position, as their carelessness may seriously jeopardise the work. Such men seldom thoroughly inspect their tools before lowering them into the well, the result frequently being fracture or detachment of portions, often necessitating tedious and costly "fishing" operations, and in some cases even the abandonment of the well: or they will allow an ambitious assistant to undertake the drilling in their absence, deliberately courting disaster: and lastly they will seldom report any peculiarity or change in the strata or even minor accidents with tools, the knowledge of which would enable the resident engineer to take steps which might avoid serious consequences.

Boreholes, except on large oilfields, are often far distant from headquarters, repair-shops, or tool-supply stores, and when difficulties occur it is often found that the tools on hand for drilling or fishing, are not suitable, and the engineer has then to devise special tools or appliances to overcome the trouble.

All engineers who have had experience of well drilling know that any stoppage or delay in the work, when once started, is in the majority of cases followed by serious results often imperilling the successful completion of the well. Stoppages of even a few hours may mean disaster, as lost tools may become so firmly gripped by loosened rock and mud as to be immovable, or the pipes standing or hanging free in the well may get seized fast by the surrounding strata settling around them, thus preventing their being moved up or down. An accident of this kind is not only very costly but also serious, for in the event of it being found impossible to free the pipe, a new column will have to be inserted, causing a reduction in the diameter of the well.

Another and frequent cause of failure in many prospect-wells is the class of tools supplied, many firms believing that the

ordering thereof can be left to their supply agent or to a clerk, in neither case (generally) acquainted with actual practical requirements, and able only to place orders as cheaply as possible. As a result tools are often supplied entirely unsuitable for the ground in which they have to be used, accessories are included which are never likely to be required, while essentials that may be frequently needed are omitted. Even well-known Companies have been known to purchase second-hand plant, which on being received and examined by the resident engineer was found to be in such bad condition that to have attempted to use it would only have resulted in disaster. Economy at all times is justified, but in the cases mentioned the tools were in a bad condition, and would never have been purchased if they had previously been examined by a competent engineer.

Engineers and others in charge of the actual field work should note, that all drilling plant and tools must be kept in a thorough state of repair: any tool showing the slightest defect should immediately be repaired, or, if this is impossible, discarded and replaced by a new tool, the discarded tool being mutilated to prevent its further use.

All plant, tools and derrick, should be minutely examined, at least once each day, by the working driller, who should immediately report to his superior any defects noticed. The engineer should also visit each well as frequently as circumstances will permit, and should examine all plant, etc., which is possible in the time at his command.

Exact, dimensioned drawings of all plant, tools and accessories should be kept at the engineer's office, each drawing numbered consecutively or in a special manner, so that the particular tool to which it refers may be easily traced. Duplicated copies of such plans should also be kept at the central office, so that in the event of any particular tool or machinery part being urgently needed, it can be obtained at short notice. By adopting this system a great deal of valuable time will be saved, and the suppliers of all plant and tools would readily furnish such drawings, as this would materially assist them in executing promptly and accurately any orders which duly indicated the reference number of the drawing.

All plant and tools should be clearly marked with a distinguishing letter or mark of ownership, class-letter and number of tool, and these letters and numbers should be cut, and not stamped, the latter method not going deep enough to withstand the wear of prolonged use.

By having all tools clearly marked with a class-letter and number, the engineer will find his duty greatly lightened in keeping record respecting the qualities of any particular tool. Similarly in stock-taking, if the numbers are registered by the storekeeper each time tools are transferred from one point to another, such marking will be found of great assistance in the event of any tool being lost, as it will be possible to readily locate exactly where the tool was last used. (The loose-card system would be readily adaptable for such registry.)

Owing to the exacting conditions of well drilling, all machinery and tools for deep well work should be strong and simple in construction, and also sufficiently heavy to overcome any unusual conditions which may be met.

In prospecting work, geologists and advisors often have to depend for guidance entirely on surface-observations in calculating the probable position of the mineral which is the object of the exploration. With mineral deposits more or less regular in stratification, the likelihood of miscalculation is not so great as with petroleum: the surface indications of which may be excellent, pointing to the close proximity of an oil horizon, but should never be relied on, as the oil exuding at the surface may have travelled from a great depth along fault-planes and fissures, and if the drilling plant is not sufficiently heavy to drill beyond the depth originally estimated, failure is likely to result.

Unknown bodies of water may be met, necessitating complete exclusion from the well, and unless the initial diameter of the well-pipe is sufficiently large to permit of this before boring is continued, success will be an impossibility.

It is therefore of great importance that all material to be used for oilfield exploration should be sufficiently heavy to permit of wells being drilled to a maximum depth. This rule equally applies to plant required for subsequent work, as it is usually found desirable to drill deeper than to the first oil-horizon. In many fields, the average depth to productive zones has shown continual increase from decade to decade.

Well-Drilling Systems. The drilling or boring systems in use are of two distinct types known as Rotary and Percussive. Both have been modified to suit different classes of strata, but the principal features of each have remained practically the same. In describing the principal types of well drilling tools, such as have been found unsuitable for oil well work will be but briefly mentioned, so that the reader may obtain a rudimentary knowledge

of them, and thus be able to recognise the special class of work for which these are best suited.

Under the term Rotary drills are included all drills which are rotated at varying speeds by either manual, horse or mechanical power, and which cut into the strata by means of a toothed cutter or an abrasive agent. The majority of these drills are used for mineral prospecting, as it is possible to recover a good core or true sample of the ground passed through, thus permitting of exact assays being made of any mineral veins which may be encountered.

The principal drills which come under this heading are the Auger, Diamond, Davies Calyx and the Hydraulic Rotary. All these, excepting the first, are worked in conjunction with a stream of water, which is pumped from the surface to the drilling face of the tools through hollow drilling-rods, the action of the water being to remove from the working face to the surface all chips and detritus which, if allowed to accumulate, would clog the drill face and prevent its downward progress.

Earth Augers. These are only used for shallow holes, seldom of a greater depth than 100 feet, and are only suitable for use where the strata consist of fairly soft material, which will permit of the tool cutting its way downwards similarly to the action of a carpenter's auger in wood.

On oilfields the auger is principally used for shallow test wells in earth, clay and alluvial deposits, sunk for geological purposes to determine the general dip of the strata underlying the superficial covering or "overburden" of earth, etc. The material brought up is not a continuous core, but is composed of parings and chips, varying in thickness according to the nature of the strata passed through and to the amount of weight pressing the auger down.

Where surface water is scarce, the auger may be used to advantage in drilling shallow wells close to the position of the projected deep well, so that a supply of water can be had cheaply for the drilling of the latter. On several fields where it is not the custom to dig pipe-shafts or cellars, frequent use is made of the auger when starting deep wells. By this means a hole of sufficient depth is drilled from the surface to permit of a complete string of tools being used from the actual start of drilling the deep well.

For deep work the auger, as already stated, is seldom used : in the case however of flowing sand, and when sufficiently strong rods are available, it may be used advantageously in cleaning out the sand, as it has not the suction-effect which is usual with the sand- or sludge-pump. By using the auger it has been possible to

lower well-pipe through rising sand 50 feet thick, the work, although slow, being accomplished without any undue heaving of the sand, and in less time than it took in neighbouring wells with the sand-pump.

The construction of auger-buckets is quite simple (Fig. 22). They are usually made out of a convenient length of pipe, but in the case of large-diameter augers, sheet iron of a suitable thickness is bent to a cylindrical form, the sides being brought together and held fast by means of an extra strip of iron plate rivetted on the inside. All rivet-holes should be countersunk, and the rivet heads made flush, wherever possible: otherwise the projecting heads will tend to impede the free passage of the auger.

To the bottom of the auger is rivetted a steel head or shoe with either one or two cutting lips. For connection with the surface, a forked piece is rivetted to the top, the extreme end of which has a screw for connection with the drilling-rods.

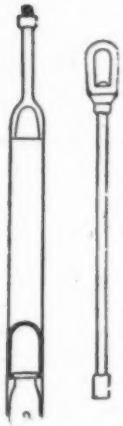


FIG. 22. FIG. 23.

The length of the auger body varies with the nature of the ground to be drilled, and the depth to which the auger can be worked below the casing without the ground caving. A suitable length however is 7 feet; should the body be made longer than this, a short auger will be needed for starting the well at the surface, as it would be impossible for the drilling crew to rotate a longer auger, unless a special stage were erected at a sufficient height from the ground.

In practice however it is found that the greater the length of the auger body, the less likelihood there is of its deviation from the vertical. Deflection of auger-drilled holes is very common, and may be caused in several ways, the principal being the shortness of the auger body, and too much hurry on the part of the workmen, who are often inclined to force the drilling without troubling about the verticality of the hole.

Another source of deflection is the presence of hard boulders in the strata, lying to one side of the hole. These can be chopped out by means of chisel bars (Fig. 23), the cutting face of which should be equal in width to the diameter of the auger. Such bars can be lowered on a wire rope, or preferably on the rods used with the auger.

In auger-drilling it is usual to have tripod derricks, sometimes known as sheer legs, which should be at least 30 feet high, so as to

give sufficient headroom above the ground to permit of the drill-rods standing in a vertical position. In starting the well, a small hole is dug about 2 feet in depth, and sufficiently large in diameter to permit of the auger entering freely. This hole should be placed vertically under the centre of the sheer legs or derrick, and is necessary as a guide for the auger, also to retain the water, without which the auger would advance but slowly.

The auger, when inserted, is rotated by the driller and his crew, who signal to the winchman when it is necessary to lower the tools further. The weight of the auger is usually insufficient to penetrate the ground, and it is necessary to add weight, by clamping to the drill rods a wooden cross bar on which one or two of the crew stand while the rods are rotated, an arrangement which saves a great deal of time which would otherwise be occupied in handling suitable weights.

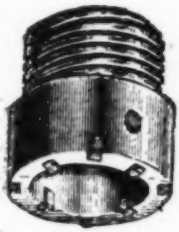


FIG. 24.

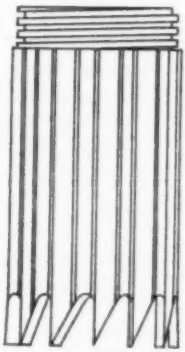


FIG. 25.

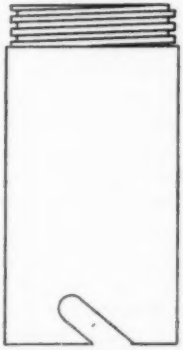


FIG. 26.

DIAMOND DRILL. This class of drill has been repeatedly experimented with on various oilfields, but has never proven a success, owing to the strata met in most oilfields being composed of clays, shales and soft sandstones, material for which this type of tool is not suited, as it is essentially a tool for hard strata.

The diamond crown, Fig. 24, being nearly flat, and working close to the drilling face of the rock, cannot make any progress in soft strata: in such ground it will within a short time churn up the strata until the clayey mass pugs or completely chokes the bottom of the borehole, and prevents the drill rotating. Consequently any attempt to use this type of drill for oilfield work will result in failure.

Davies Calyx System. In principle this very closely resembles the diamond drill, the difference being that instead of diamonds an all-steel boring head or cutter is used, the working face of which is serrated as shown in Fig. 25. As originally designed, it is essentially a soft-strata coring drill, and some remarkably quick drilling has been accomplished in small holes with it, but hitherto it has not proved a success for oil well work, several causes no doubt accounting for this non-success, the principal being that owing to the large diameter necessary in oil-well drilling, the cores are difficult to recover, and a great deal of valuable time is consequently lost. Unlike the hydraulic rotary the flushing water must be fairly clean, as otherwise the thick mud, which prevents caving with the hydraulic rotary, would erode the sides of the core, and make it more difficult to recover: the well pipe therefore has to follow the tools closely, as otherwise the ground may cave and bury them. By having to keep the well pipe always so near the bottom of the well, there is every likelihood of its sticking fast before it has been sunk to the requisite and estimated depth. There is however sufficient evidence that this drill can be improved and become a most satisfactory tool for work on a developed oilfield. Of late years many improvements have been made so as to adapt the system for mineral prospecting. Those effected in the United States have placed this system in the front rank of mineral prospecting tools, and it is now claimed to be superior to the diamond drill, as it will drill in soft strata at a speed hitherto unequalled, recovering at the same time a higher percentage of core than is obtainable by any other class of drill. To overcome the difficulty of drilling at economical speeds in hard strata, the use of chilled shot as the abrasive agent has been adopted. The shot used vary in diameter from a sixty-fourth to an eighth of an inch, and act on the hard strata similarly to the bort of the diamond drill. The cutter or crown used for operating with chilled shot is known as a "drag shoe," Fig. 26, the shot required being fed automatically and at a speed corresponding to the requirements of the drill.

By means of the chilled shot good cutting speeds have been obtained in very hard strata, the work, although in some cases slower than that which obtained by the diamond drill, is accomplished at very much lower cost, and it is only reasonable to forecast that the diamond drill will eventually entirely be superseded by the improved Davies Calyx.

With the serrated cutter, it is not necessary to revolve the tools at a high speed, the usual rate varying from 5 to 10 revolutions

per minute. In working with shot in hard strata, a much faster speed is necessary, and it has been found in practice that a speed approximating that used with the diamond drill is most suitable. To accomplish this high speed, the rotating machine has been improved along lines similar to those of the diamond rotating and hoisting machines, permitting the rotation of the drill at varying speeds to suit the hardness of the strata encountered. These machines are compact, easily transported, and so constructed to permit of wells being drilled at any required angle from the vertical.

Hydraulic Rotary. This, though somewhat similar in principle to the two preceding systems, differs in yielding no cores, except by the addition of special coring cutters. It is essentially made for use in soft strata, and is of little service in hard rocks. Since all the material penetrated is cut away, and carried to the surface by the stream of water, no time is lost in recovering cores as with the Davies Calyx. Also since thick mud is used instead of clear water, there is no necessity to lower any string of well pipe until the desired depth is drilled to which it is intended to take it. The thick mud not only prevents the walls from caving, but also plasters them up, completely filling all crevices and cracks by which the water might escape from the well into the surrounding strata. By this means wells can be drilled to depths of 1,200 to 1,500 feet in soft ground without any pipe except that used at the surface as a guide column and to prevent the erosion of the mouth of the well by the return water flow. This is the only system of drilling which permits of such a depth being drilled without casing in soft strata, and is made possible by the use of the thick mud and the rapidity of drilling, depths of 75 to 100 feet per 24 hours being frequent records.

Of late years this drill has been extensively adopted for oil-well drilling, and its use is being further extended on proven oilfields, where the depths of the various oil-horizons are exactly known.

For oil-prospecting in unproven territory, the hydraulic rotary is not recommended, as it is quite easy to pass by a paying oil-horizon without any indication of its presence being noticed, the thick mud which is used for the drilling tending to force back from the vicinity of the well any oil that is not under a pressure greater than the head of liquid mud standing in the well. In the same way, the " mud " prevents the accurate detection of water-bearing beds, and as it is of vital importance that all water be completely shut-off, and excluded from the interior of the well before the oil-horizon is reached, it will at once be realized how

dangerous it is to use this system for prospecting in unknown ground. The only exception in which it should be permitted is in cases where the formation met is composed of loose sand and shales liable to cave or "heave" (rise suddenly in the well), such strata being very difficult to drill in with percussive tools.

In many oilfields, several horizons are exploited at the same time, shallow horizons, in which no heavy pressure remains, often continuing to produce oil in small but paying quantities for long periods after the wells have been drilled, whilst newer wells are carried to deeper and more productive horizons. In such fields it is usual to drill the wells close together, and it is in cases of this kind that there exists great danger in using any water-flush system of drilling, as there is always the risk of the thick mud and water used in the drilling entering these shallow horizons and driving the oil away.

It is claimed that this danger can be minimised if the drillers are instructed to use either very thick mud, or oil instead of water, when nearing and passing shallow and productive oil sands, or if a combination rig of rotary and percussive tools be used, the percussive system only being applied when there is any danger of damage to producing sources by the use of the rotary. Either of these procedures would certainly minimise the danger of flooding producing sources, but it is doubtful if they would be effective in all cases. The most practical method would be to lower a special column of well pipe, and set it securely below each oil sand, so that any shallow producing horizons would be effectually shut off. This method, however, would necessitate separate strings of well pipe for each horizon, and would consequently be very costly, as the initial diameter of the well would have to be sufficiently large to permit of several strings being abandoned at the shallow sands, and still allow the well to be drilled to the more productive and deeper horizons. As such increase in the initial diameter of the well would mean a much higher capital expenditure, it is questionable if operators would agree to this method.

Although in principle similar to other water-flush tools, the hydraulic rotary differs very much in detail. The drilling bit, Fig. 27, is screwed direct into the drilling tube or stem, for which it is usual to use a special-made pipe, varying in diameter from 3 to 6 inches according to the size of the intended well. The stem extends to the surface, at which point the water swivel (Fig. 28) is screwed into the top. The stem is rotated by grip-rings or other means attached to the rotary table, Fig. 29.

On the introduction of this system in California, it was found

that the rig, etc., as used in Texas and Louisiana, was too light for the much heavier work necessitated by the deeper wells in that country, and many improvements were found necessary, the most important being the addition of what are known as tool-joints, Fig. 30, to the drilling stem. By using these joints, instead of the ordinary pipe couplings, at the points in the stem where

FIG. 27.

FIG. 30.

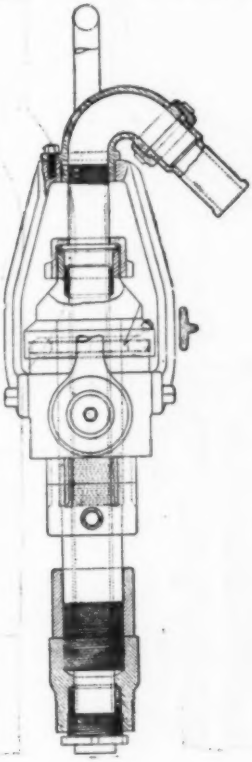


FIG. 28.

it is necessary to couple and uncouple each time the tools are inserted or withdrawn, a great economy has been possible in time and money. The pipe and coupling threads under the old system had frequently to be renewed, owing to the wearing away of the threads in the continuous screwing and unscrewing.

The new joint, being made of mild steel, lasts much longer than the iron-pipe coupling, and owing to the conically tapering pins used, they are unscrewed in a much shorter time than was formerly possible with the old type of joints; also as the wrenches used for unscrewing grip the joints, the drill stem is not damaged,

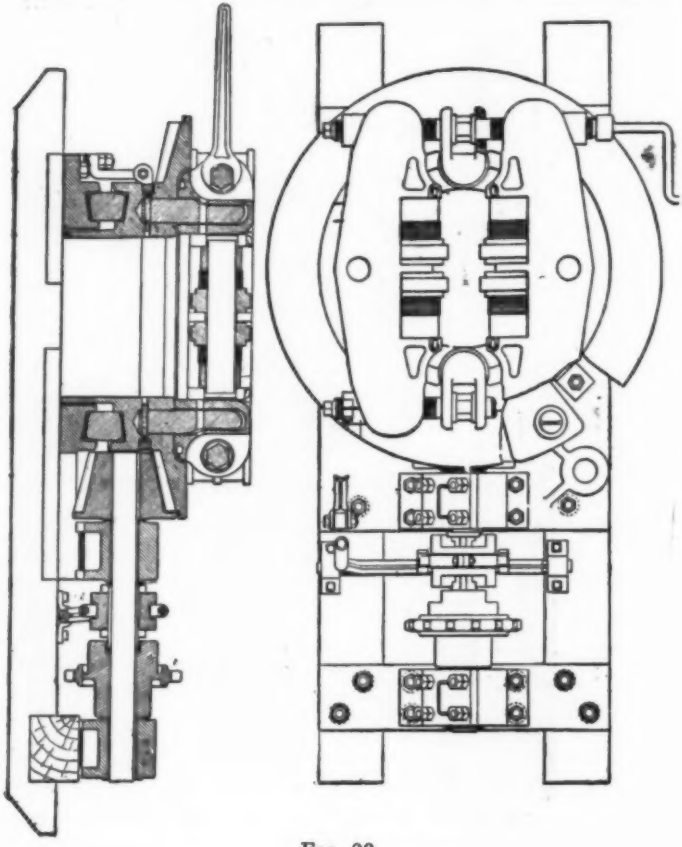


FIG. 29.

as was the case when pipe tongs had to be used on the pipe for unscrewing.

The usual drill-stem pipe, being thin, soon becomes dented and grooved owing to the slipping of the grip-rings, but this has

partly been remedied by always using a specially thick pipe at the surface for working in the grip-rings, adding the requisite pipes below the thick top pipe as the well deepens. This thick pipe however is not quite satisfactory, as frequent renewal is necessary in the grip-rings and pipe, and an undoubted improvement which has just been introduced is the use of rotating stems of square or hexagonal section, these being rotated in both cases by means of heavy clamp plates instead of grip-rings on the rotary table. In practice it will undoubtedly be found that this plan will obviate what has been one of the most expensive drawbacks to the more extended use of the rotary. Similar square stems have been used for a considerable period with the larger types of Davies-Calyx drills, and have always given satisfaction. By the introduction of these various improvements the expensive wear and tear which formerly occurred with rotary tools will have been overcome.

Wherever possible, it is advisable that the derrick for rotary tools should be at least several feet above the level of the surrounding ground, so that the return water from the well will flow freely to the settling pits, all of which, except the one from which is pumped the water required for the drilling, should be at some distance from the well, so that the muddy return water, may deposit in the connecting water channels the greater part of the sediment held in suspension, and by the time it reaches the pump-suction pit be sufficiently liquid for drilling-purposes. If the various settling tanks are placed at some distance apart, most of the sediment will settle in the channels, from which it may be quickly removed, without the necessity of stopping the drilling, as would happen if the pits themselves had to be cleared. The settling pits should never be less than 10 feet square by 5 feet deep.

In the event of a change in strata necessitating thicker mud, this is readily obtainable by throwing back into the water-channel sufficient sediment which had formerly been cleared therefrom provided that it is not too sandy. Wherever possible, it is advisable to use fairly clean water for the drilling, as the continual abrasion by the coarse sediment in the thick mud soon wears away pump-valves and other working parts. Consequently the finer material from the last of the settling pits will be the best to use when needed.

The operation of the hydraulic rotary is fairly easy, and may soon be learned by any careful workman. Previous to lowering the tools the driller in charge should carefully examine the draw-works or hoisting winch (Fig. 31), rotary table, water swivel,

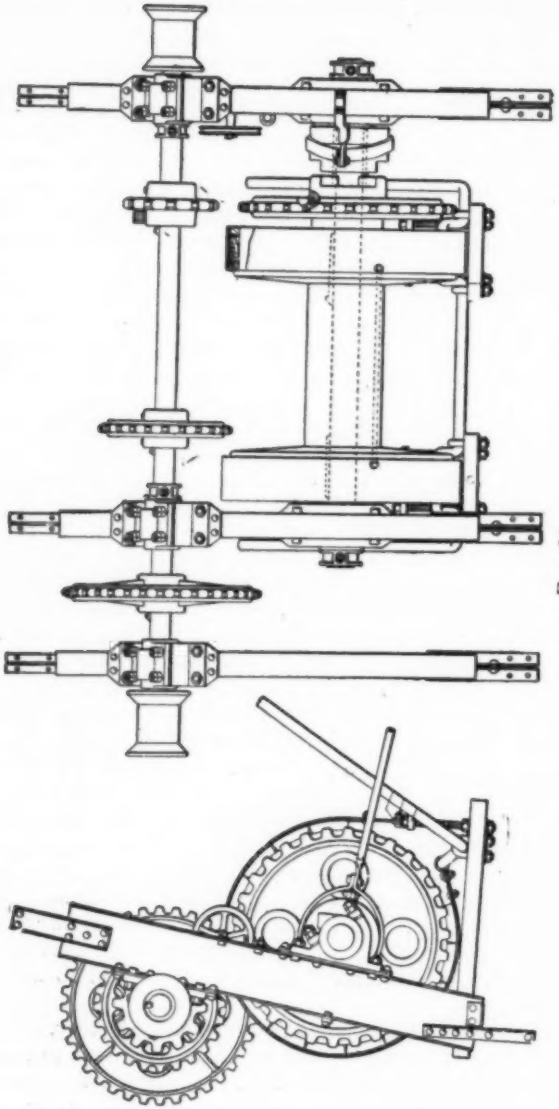


Fig 31.

pumps and all other working parts, so as to be certain that all are in good order, and not likely to require repair while the drill is in operation.

In starting a new well, it is usual to fix vertically and secure tightly one length of casing in the pipe shaft or "cellar." Should the depth of the latter not permit of this, the rotary drilling stem must be plumbed, and held absolutely vertical by means of guides or cross stays securely fastened to the derrick. In this manner sufficient depth may be drilled to allow for at least two lengths of well pipe being lowered to act as a guide column. Very few drillers will take the trouble to place and secure a guide column accurately, and as a result of this negligence many wells give trouble from the start, owing to crookedness.

On the well being started, the drilling stem should be revolved slowly. Another and most important point, is that the pump should not be worked at a pressure greater than that required to force the water back to the surface, otherwise the light weight of the tools in a new well may be lifted clear off the bottom. In the event of the minimum pressure being found too great for the short drill-stem, extra weight should be added by clamping elevators, pipe clamps and other heavy material to the stem. Care should be taken that all such additional weight is securely fastened, as otherwise, when the drill is rotating, they may fall off with the momentum, and possibly injure one of the crew.

As soon as it is found that the drilling-bit is cutting satisfactorily, the speed of rotation should be gradually increased, but a maximum of 40 revolutions per minute should not be exceeded whilst the well is still shallow, and the stand-pipe or guide-column, used for retaining the surface soil, has not been inserted. When the latter is in position (and usually 60 to 80 feet of pipe is ample for this purpose), the drilling speed may be increased to the maximum; the pump-pressure, however, should never be increased above what is necessary to keep the face of the bit clean, and force the water back to the surface.

In drilling the tools should never be lowered too fast, the best work being done with the drill just touching the bottom of the well, with only sufficient pressure on the bit to assist its descent.

In hard shale drillers usually run with all the weight of the stem on the bit, a bad practice which should not be permitted, as the bit frequently jams, and if the stem is not immediately lifted, the bit is only freed after a great deal of torsional strain has been applied by the rotation, resulting in weakness in the stem which may eventually lead to its fracture by "twist-off," and the

necessary fishing for the lost tool. The continued strain also tends to unscrew the water-swivel, which, to work properly, must always have a good load to carry. Finally there is also the likelihood of the hole being deflected from the vertical, a mishap which frequently takes a considerable amount of time to rectify.

Frequent trouble is encountered after the well has been drilled to a considerable depth, from the water not returning properly to the surface, the drill having entered a crevice in the rock, or possibly a bed of dry sand. In such cases it is customary to make the pump-water as thick as possible, by adding, as already described, extra mud to the liquid in the settling pits. Should this however not have the desired effect, chaff, chopped straw, stable sweepings, bran or small grain of a quickly expanding nature may be added to the thick mud, and will be found effective.

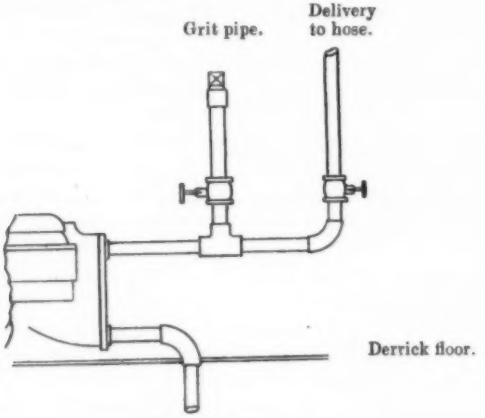


FIG. 32.

Whenever the return water stops flowing at the surface, it is advisable to slow down the speed of rotation, but on no account should it be completely stopped; the further lowering of the drill stem also should be done very slowly, as the sediment from the newly drilled ground will assist the material pumped into the well to plaster the walls of the well more readily.

In certain clays, the bit-face frequently becomes "pugged up" or clogged owing to the adhesiveness of the clay. In such cases the water-pressure should be increased as much as possible, and very fine broken brick, small cinders or coarse sand added to the water will materially assist in clearing the bit-face. The intro-

duction into the water of such material can easily be done by means of a short stand-pipe added to the pump-delivery pipe, as shown in Fig. 32. By making this connection, the working parts of the pump will not be damaged by the grit, the supply of which can be regulated to suit requirements.

In the South Eastern Oilfields of the United States, where it is usual to drill the wells entirely with rotary tools, the return water is very carefully watched, and immediately any indications of oil or gas are noticed, the well is thoroughly flushed with clean water, and, should the indications improve, a trial baling is made, all the liquid standing in the well being completely removed. This is the only means whereby exact knowledge can be obtained respecting an oil-source, which, although not under great pressure, may be of value for exploitation. In some cases even prolific spouting wells have only been discovered after all the mud and water has been removed, and it is therefore of the greatest importance that the return water be carefully watched at all times. This rule should be enforced from the start of the well. Oil indications in the return water usually take the form of small globules on the surface, and can readily be seen in the day time, but when drilling is continued at night, it is difficult to notice these signs, and a careful examination should be made each morning of the water surface in the settling ponds or pits, where the globules of oil usually collect and form a scum.

FIG. 33.

Owing to the erosive action of the water on the walls of the well, it is very probable that in soft strata cavities are formed much larger than the outside diameter of the well pipe, and it is therefore advisable, that previous to setting a column of casing, the drilling bit be reduced, and a hole of smaller diameter drilled some distance below the point which it is intended that the casing should reach. By doing this, the well pipe, if fitted with a serrated shoe (Fig. 33), can be rotated and forced into the smaller hole. In this manner troublesome top waters may frequently be effectually and permanently shut off, and also, in the event of the well having to be capped (closed with a gate-valve) there will be more likelihood of the ground gripping the casing tightly, and thus preventing its being blown out by the enormous pressures sometimes met in new wells.

Should it be necessary to use several columns of pipe in the well, these, unless partly cut out, will all necessarily extend to the surface, in which case it is most advisable that care be taken

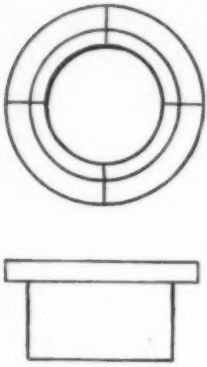


Fig. 34.

thoroughly to block up the space between each string, otherwise the sediment held in suspension will be apt to settle between the pipes, and as such sediment usually settles very tightly, it will be found very difficult to withdraw the pipes, should this be necessary at any time. To prevent the sediment finding an entrance, it is customary to wrap wide strips of canvas around the top of each pipe, but this is not always sufficient, and it is advisable to have wrought-iron segment rings, as shown in Fig. 34, accurately turned to fit the space between the pipes, not only preventing the sediment finding an entrance, but also serving as a good sole-plate for pipe-clamps which may be holding up succeeding columns of pipe.

A better method would be the use of a T piece, by which all return water is carried clear away from the cellar, leaving it completely dry. One T piece will be found sufficient for each well, using short reducing nipples as the diameter of the well pipe is reduced.

Owing to the muddy water used for drilling being very gritty, all working parts of the water-cylinder ends of the steam-pumps soon wear away, and they should therefore in all cases be fitted with removable cylinder liners and adjustable plungers, the latter being packed with good hemp or similar packing. Valves and valve-seats should be so constructed as to be readily and easily removable as they require frequent renewal. In many American oilfields a pure soft-rubber valve is preferred, but as renewals are so frequent, and the price of the valves is very high, a hard-rubber composition valve might be preferable, and would be not only cheaper but also of longer life, for it would be possible to reseat the face several times, this being done in a lathe by a skilled turner.

Percussion Drills. The systems classed under this heading are those by which the drilling is done by chisels attached to heavy bars suspended from a beam, which is operated, either manually or mechanically, so as to give the tools a reciprocating motion.

The principal types of percussive drills most extensively used for oilfield work are those known as the Pennsylvanian Cable, Canadian Pole tool, and the Russian Freefall. Many attempts have been made to introduce modifications of these tools, but the majority have failed. In most of these attempts, endeavours

have been made to make the tools automatic, but it is very improbable that any device will be found to supersede the human factor, the vagaries of the strata met with in all wells absolutely demanding that any such device should automatically adjust itself to suit the frequent changes.

The only improvements which have been adopted are in connection with the drilling rigs, *i.e.* reciprocating machines. These of late years have been improved in many ways—and there is still room for further advance. All such modifications, however, should be free from complication, and so constructed as to be able to withstand the heaviest wear and tear. Oil-well drilling to be satisfactory, has to be speedily accomplished, and if the driller has to operate a complicated or delicate piece of machinery on the surface, he will not be able to give the necessary attention to the drilling work, which is of primary importance.

Pennsylvanian Cable Tools. As the name implies, the principal feature in these tools is the cable by which they are suspended and connected to the walking-beam. These tools, practically in their present form, were first extensively used for oil-well drilling in the State of Pennsylvania, whence their use has been extended to the principal oilfields, not only in the United States, but other parts of the world.

For prospecting work in unknown territory, and in the hands of competent drillers properly supervised, the cable system will be found to give most satisfactory results, as proof of which may be cited the vast oil development which has taken place of recent years in the United States, the majority of the new fields having been discovered by means of cable tools.

Within the past two years great strides have been made by rotary tools, and by many it is thought that the latter will supersede the cable tools for all classes of oil-field work. This however is very doubtful, as operators, when they discover the heavy cost entailed by the rotary system, and the impossibility of using it in hard strata, combined with the chances of paying oil being passed by careless or unscrupulous drillers, will naturally revert to the old class of tools, and will only make use of the rotary where geological conditions are exactly known, or where the formation is composed of heaving sands and loose shales—strata in which percussive tools have proved unsatisfactory.

The string of cable tools (Fig. 35) is composed of the following :—

Drilling bit, auger stem, jars, and rope-socket. At the surface the drilling cable is held by the temper screw, which is suspended from the walking-beam of the drilling rig (Fig. 36).

By means of the temper-screw, the driller is able to lower the cable as the drilling progresses.

As used in Pennsylvania the cable drilling rig and tools were of

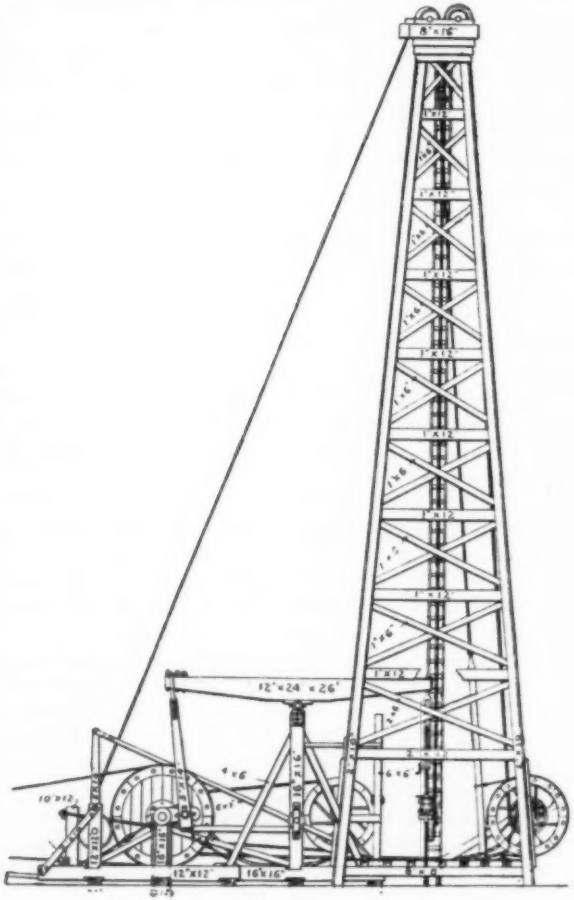


FIG. 36.

very simple construction, the formation being of a sufficient hard nature did not cave, and well pipe was only lowered when the full depth was drilled for that string. When it was necessary to lower

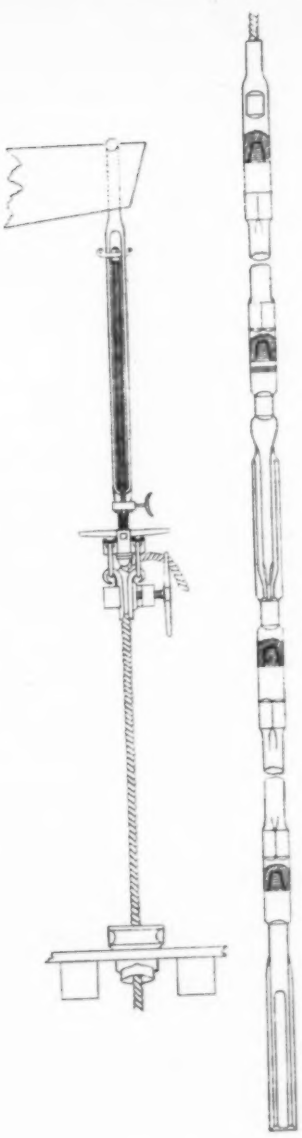


Fig. 35.

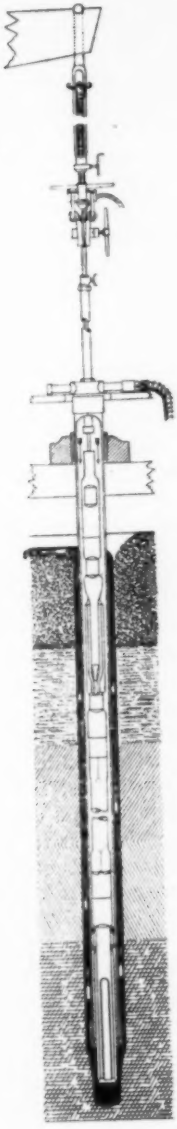


Fig. 38.

the well pipe, it was usual to unwind the drilling cable from the bull wheel, and in its place to wind on the tackle-block rope. The drilling bits being thin, usually not exceeding 3½ inches in thickness, necessitated the continuous twisting of the cable backwards and forwards, so as to give the necessary circular motion to the bit.

On other fields being discovered where the oil was deeper and the strata not so coherent as in Pennsylvania, larger diameters of well pipe were necessary, and improvements had to be made, the principal being the thickening of the drilling bits, the thickness being increased to as much as two-thirds diameter of the hole to be drilled. By increasing the thickness of the bits, it was found that there was no necessity to twist the cable backwards and forwards, as the swing of the tools was ample to give the latter sufficient axial movement to permit of a circular hole being drilled. In fields where the rock was very incoherent and caved, it was found impossible to work without the pipe following close on the tools. To do this on the old Pennsylvanian type of rig meant frequent winding of the cable off and on the bull wheel, so as to permit of the well pipe being handled with blocks and tackle. This frequent changing of ropes occupied a lot of time, and to overcome the difficulty the calf wheel was added, by means of which the pipe can now be quickly raised and lowered, without necessitating the removal of the drilling-cable from the bull wheel, whilst any necessary working of the pipe can easily be done without any lengthened stoppage in the drilling work.

In the drilling of shallow wells, it is usual to use Manilla cable, varying in thickness from 1¾ to 2¼ inches, the diameter most favoured being 2 inches. Many attempts have been made to use steel wire ropes, but, except for deep drilling, these have not become of general use. No doubt the small diameter of the bull-wheel shaft tends to break the individual wires of which the rope is composed. Another cause preventing the more extended use of wire ropes is the frequent breakage near the rope-socket, undoubtedly caused by the driller working with a very slack rope, and permitting it to kink and twist back, so that immediately the weight of the tools is brought on the rope, the wires tend to break at the kink. By increasing the diameter of the bull wheel, and using long-bodied swivel rope-sockets (permitting extra long springs to act as shock absorbers when the weight of the tools is brought on the rope) the defects mentioned would no doubt be overcome, and a more general use of wire ropes might be practicable.

Manilla cables soon deteriorate in wet holes—that is wells where there is a high column of standing water, and it is therefore advisable to keep the well as free from water as possible. Instead therefore of permitting water for drilling to run into the well from the surface, it should be "dumped," by filling the baling bucket and lowering it to the bottom of the well, when the conical bucket valve is lifted by means of the attachment shown in Fig. 37 (screwed to a length of pipe), letting the water escape into the bottom of the well without wetting the walls. By dumping the water, not only is the cable kept dry, but also the drilling can be done much faster and easier. The depth of water allowed in the well should not exceed 35 feet from the bottom, as with this short column of water the tools lift and drop much more freely, whilst this amount of water is just sufficient to mix the drillings to a thick mud, which can be much easier and quickly cleaned out than if the mud is more liquid. By this means also each individual string of well pipe can be carried much deeper than is possible in a wet hole, or where the water is run in from the surface, as in the latter case it wets not only the walls of the well pipe and the cable, but also any uncased ground, which thus becomes saturated with water very much in the same manner as when a big head of water is carried, the saturation causing the ground to swell and cave, and preventing the free passage of the well pipe.

FIG. 37.

In loose formations such as sands and broken shales, the carrying of a big head of water cannot be avoided, as it is only by its means that any headway in the drilling can be made. In cases where it is absolutely necessary to drill with a wet hole, a wire rope should be used instead of a Manilla cable. In some of the Californian fields great difficulty was met in drilling through incoherent and soft strata, and despite the fact of the wells being kept always full of water very slow progress was made. To overcome the difficulty, water flushing was introduced, being applied by means of the well-pipe head and slide rod shown in Fig. 38, the pumps for pumping the circulating water being similar to those used for the hydraulic rotary.

By means of the water flushing, some very successful work has been accomplished, but, owing to the introduction of the hydraulic rotary, and its combination with the cable system, a more extended use of this water flush has not taken place. Its addition to the cable tools will be found of great assistance in prospecting in new fields, where it may be found that the formation is of a loose

character. To work the water-flush successfully, the well pipe must always follow the tools closely, so that the return current of water will clear away all debris from the face of the bit, and carry it to the surface, whilst by passing up outside of the pipe, it also necessarily flushes its surface, and clears away any loose strata which may be holding it.

According to the latest drilling practice, cable bits are dressed, not chisel-edged, but with a concave face as shown in Fig. 39. This peculiar dressing of the bit face would at first sight appear to retard instead of increase the cutting speed, but if the water channel shown in the bit section is made as deep as possible—the metal between the two channels usually being approximately equal to a quarter of the total thickness of the bit—it will be found that very much faster work can be done than with the chisel-edged bit. During recent years drilling bits have also been very much increased in length, many engineers and contractors specifying lengths of as much as 7 feet, as it is claimed that, by increasing the length of the thick-bodied bits, there is less likelihood of the tools diverging from the vertical, and thus producing a crooked hole. Also in the event of the bit being detached through unscrewing or breaking, it is more easily recovered, as it cannot so easily fall to one side, as frequently happened with the thin short bits formerly used.

FIG. 39.

Until recently it was the practice to make the drilling-bit shanks and parts of the body of wrought iron, welding on the bit-point, 70 to 100 lbs. of steel according to the size of the bit. This has now been discontinued, and bits are mostly made of steel throughout, by this means obviating the accidents which frequently occurred with the old bits through fracture at the weld. All-steel bits are much costlier than the old pattern, but the cost can be greatly reduced by having the stubs of large bits (that is the worn ends which can no longer be used with safety) drawn out, and made into smaller bits. It was also found that the wrought-iron face of the drill stem box wore out very quickly, to obviate which steel-faced box-joints have been introduced, not only increasing the friction-hold of the joints, and preventing their unscrewing, but in most cases trebling the working life of the tools, that is provided the drillers always take care thoroughly to clean and polish with sandstone the joint-faces before screwing them up. Such polishing

is often considered a waste of time, but it is only by keeping tools in perfect condition that good work can be accomplished.

All drilling-bits should be frequently dressed, and thus kept up to the full gauge or original diameter, and circular gauges for this purpose should be included in all drilling-tool specifications.

Many engineers and drillers complain that, where the strata are not exceptionally hard, the cable-tools do not give sufficient underreaming to permit of each column of pipe being sunk to a proper depth. This should not happen if the bits are frequently dressed and kept up to the original gauge: in fact where the strata is so hard as to necessitate continuous underreaming, the well can remain without pipe. Where hard rock occurs in patches amongst soft strata, thus necessitating that the pipe follows the tools closely, as is frequently the case for instance in the Californian fields, it is customary to use underreamers. Of these there are various patterns, the "Swan" and "Dobell" types being the most favoured. Underreamers cannot however be used in conjunction with the drilling bit, and it is usual to drill about 25 feet with the bit, then to underream the drilled depth, and immediately lower a section or joint of well pipe. In soft strata, composed of clays and shales the swing of the drilling tools enlarges the hole sufficiently to permit of the pipe passing down freely, but there are certain clays and shales very liable to swell. Such strata frequently occur in coal mines, and cause a great deal of trouble, tending to creep or squeeze into the levels and other passages, and eventually to block them up completely if not attended to. Creep in coal mines is supposed to arise from the weight of the overburden or top strata pressing on the soft clay or shale bed, and where a clay swells in a well which has been drilled with a minimum of water, it is quite feasible to presume that the cause of the swelling is similar. It therefore follows that the larger the opening made, and the longer it remains uncased, the greater will be the inswelling of the strata. Consequently underreaming, which increases the diameter, only tends to intensify the evil, and the best remedy is to drill as expeditiously as possible, which, provided all plant and tools are in good order, will not be found difficult, for the majority of swelling clays permit of quick drilling. It may however occur that, even with quick drilling, the clays swell in so quickly as to hold up the casing. When this occurs, it is usual to drive the pipe by means of repeated blows on the top, similarly to the manner in which wooden piles for river and other foundations are driven into the ground.

Drill stems vary in diameter from 3 to 5 inches, and are usually

between 28 and 38 feet in length. Where the tools have frequently to be moved to new well sites, it will be found that such long stems are liable to get bent in transit, from the continual sagging which occurs even when the stems are transported on properly constructed carts. No stems should therefore ever exceed 28 feet in length, and where a longer and heavier stem is required, it should be composed of two pieces.

Above the drill stem are screwed the drilling-jars, which in construction resemble two links in a chain, and are necessary to give the tools the requisite " blow " or shock to release them from the rock wherein they may have become jammed. To the top of the jars is screwed the rope-socket, of which there are various types, but the most practical and trustworthy is that known as the " New Era." The rope-recess in this is tapered in such a manner that the enlarged end of the cable on being drawn through the opening tends to tighten as the strain is increased. To enlarge the end of the cable, all that is necessary to be done is to cut off about two feet, and shred the strands of the piece, the shredded strands are then inserted in the cable end, and the latter pulled through the socket.

In former years it was deemed absolutely necessary to have a sinker-bar placed between the jars and rope-socket, as it was contended that the rope did not fall quickly enough, and thus it partly checked the drop of the tools. Sinker bars are now seldom used except on fishing tools, but their use is recommended, as they undoubtedly help to put a strain on the cable, and thus partly prevent it flogging the walls of the well, which materially shortens the life of the cable. In diameter sinker bars usually are similar to the drilling stems, but the length seldom exceeds 12 feet.

In ordering cable tools, an item of great importance is the exact specifying of the tool-joint dimensions. It should also be noted that as each manufacturing firm makes the screw-threads on tool-joints to private gauges, tools ordered from different makers, although of the same dimensions, will seldom fit accurately together, and if used, will in the majority of cases result in serious fishing-jobs. Should it however be desirable to obtain supplies from various makers, it is advisable to have one's own private gauges, forwarding them to each toolmaker as orders are placed. In no case should the screwing of tool-joint threads be done by lathe turners who are not fully acquainted with such work, as the slightest inaccuracy, either in taper or finish, of any particular joint, may mean the complete ruin of a set of tools.

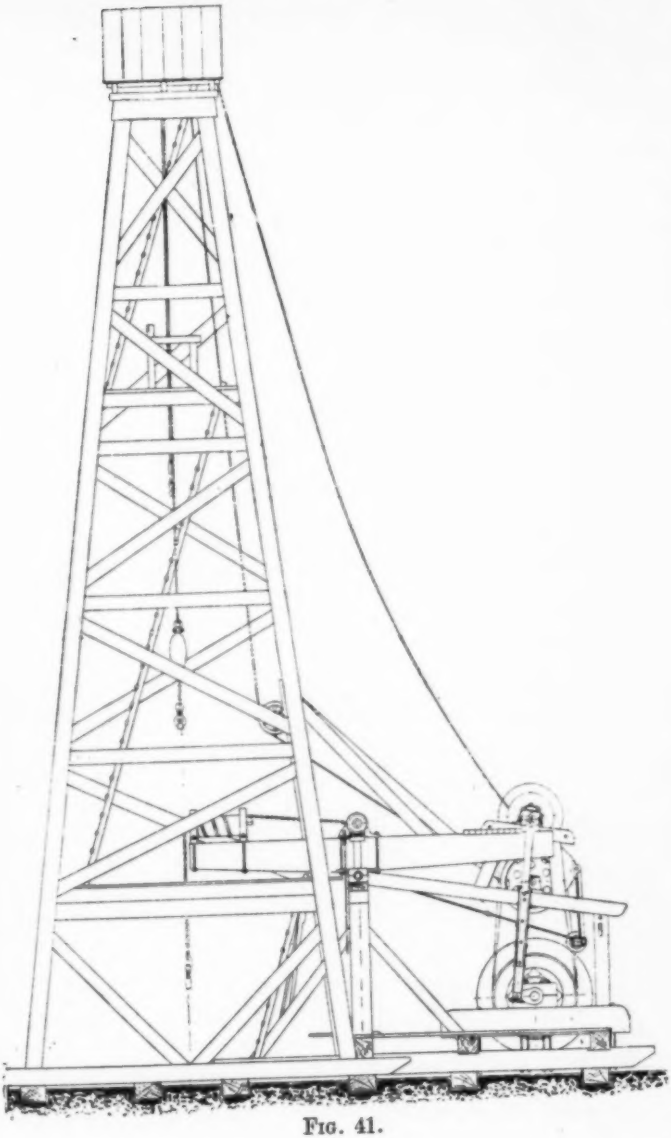


FIG. 41.

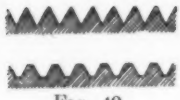


FIG. 40.

For large-size joints it is advisable to specify a flat thread, Fig. 40A, as this will not wear out so readily as that shown in Fig. 40B, which is usually ordered for small-size joints, where the friction-hold between the joint-faces is not so great as in the larger joints.

TABLE OF AMERICAN STANDARD TOOL JOINTS.

Size of Joint.	Diameter of Collar.	Usual size of Stem.	Suitable for Pipe.
$1\frac{3}{8}$ in.—2 in. ...	$2\frac{7}{8}$ in. ...	$2\frac{3}{4}$ in. ...	4 in. or larger.
$1\frac{5}{8}$ „ —$2\frac{1}{2}$ „ ...	$3\frac{1}{2}$ „ ...	3 „ ...	4 „ „
2 „ —3 „ ...	$4\frac{1}{4}$ „ ...	$3\frac{1}{2}$ „ ...	$5\frac{1}{2}$ „ „
$2\frac{1}{4}$ „ —$3\frac{1}{4}$ „ ...	$4\frac{1}{2}$ „ ...	$3\frac{1}{2}$ „ ...	$5\frac{1}{2}$ „ „
$2\frac{1}{2}$ „ —$3\frac{1}{2}$ „ ...	5 „ ...	4 „ ...	6 „ „
$2\frac{3}{4}$ „ —$3\frac{3}{4}$ „ ...	$5\frac{1}{4}$ „ ...	4 „ ...	$6\frac{1}{2}$ „ „
3 „ —4 „ ...	6 „ ...	$4\frac{1}{2}$ „ ...	$7\frac{1}{2}$ „ „
$3\frac{1}{4}$ „ —$4\frac{1}{4}$ „ ...	$6\frac{1}{4}$ „ ...	5 „ ...	8 „ „
$3\frac{1}{2}$ „ —$4\frac{1}{2}$ „ ...	$6\frac{1}{2}$ „ ...	6 „ ...	8 „ „
4 „ —5 „ ...	7 „ ...	6 „ ...	8 „ „

CANADIAN POLE TOOLS. These are percussive tools, and although the system differs slightly, they are practically similar to those used with the cable system, the essential difference in the two systems being poles instead of a cable connecting the tools to the surface. Formerly ash-wood poles were used for this purpose, but of late years a sufficient supply of suitable ash poles has not been obtainable, and iron rods have been substituted therefor. The iron poles now used are round, and vary in diameter from $\frac{3}{4}$ to $1\frac{3}{8}$ inch. They are preferable to wooden poles, as they can be welded into rods of the exact length required: the wooden poles seldom exceeded 20 feet in length and as this length was too short for practical work, the poles were joined in lengths of two, the spliced ends being held together by means of rivetted straps of iron plate.

With pole tools, no temper-screw is used, the necessary lowering or feeding out of the tools, as the drilling progresses, being accomplished by means of a chain which passes to a small winch (slipper-out) placed above the centre of the walking-beam. To avoid unnecessary strain on the slipper-out, the drill-chain is several times passed round a cast-iron drilling head (chain-jacket) which

FIG. 42.

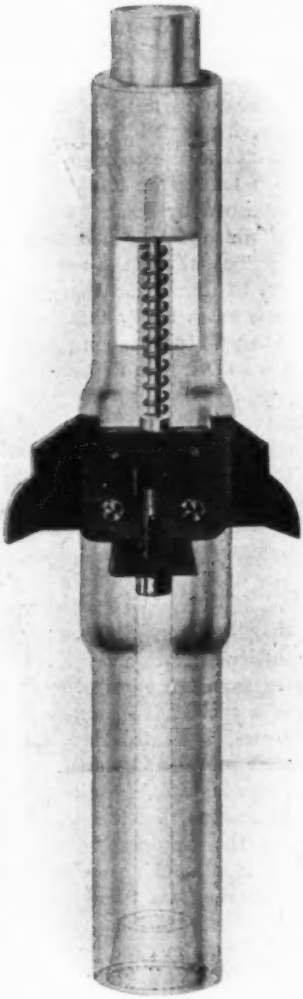


FIG. 43.

FIG. 45.

is bolted to the extreme end of the walking-beam, directly over the centre of the well.

The rig used with these tools differs very much from the cable rig, and is not so powerful. As will be seen from Fig. 41, the rope reels (drawworks) are placed at some height from the ground, usually about 10 to 12 feet, the necessary power being transmitted from the driving shaft by means of wide leather belts, sufficiently slack when not in use to hang free from the driving spool pullies. Sufficient tension on the belts to transmit power to the reels is accomplished by means of swing pullies (jockey pullies), the tension of which on the belt suffices to operate the reels for ordinary work, but where it is necessary to handle pipe in heavy ground it will be found that the jockey pullies are not powerful enough—unless extra heavy tackle-blocks are used.

The advantages of the pole tool system are that (1) for shallow wells of not more than 1500 feet in depth it can be operated by men of less experience than is necessary with the cable tools, (2) the poles having to be continually rotated avoid the possibility of a crooked or " flat " hole, (3) the working of the tools, besides being under the control of the driller operating the slipper-out, can also be controlled by the man rotating the poles, who can remind the driller if the tools are not working satisfactorily, (4) the drilling rig generally is not so cumbersome and unwieldy as the cable rig, many of the parts of the latter, especially the bull and band wheels, being very awkward to move from place to place, and (5) when the poles break, they can quickly be rewelded to their former lengths, suitable iron being always obtainable at points not far removed from the place of work, whereas when a drilling cable breaks or is spoiled, it cannot be replaced so readily, more especially if the well is in a country f..r distant from the centres where the cables are manufactured.

Despite the much slower rate of drilling, it is undoubtedly owing to the foregoing reasons that the pole system has been so extensively adopted in the European, East Indian and other fields, where local labour, although poor in quality, is plentiful and cheap. In these fields it is usual to have a thoroughly experienced driller as overseer, who superintends the working of several rigs when the wells are in close proximity to one another.

Owing to the tools being continually rotated, the bits used with the system are not very thick, usually about $3\frac{1}{2}$ inches. Recently there has been introduced an ex-centric bit, Fig. 42, by means of which the walls of the well are sufficiently cut down or underreamed at the same time as the well is being drilled, thus

avoiding the loss of time necessary for working with special tools to enlarge the well sufficiently for the free passage of the pipe.

The underreaming side of all ex-centric bits should be as wide as possible, usually not less than 4 inches, which is desirable so as to leave no ridges or lumps on the walls of the well, which would impede the free descent of the pipe. The extreme underreaming which can be done by these bits is 1½ inch on each side of the well, thus increasing the diameter by 3 inches, an amount sufficient to permit of a string of pipe being carried to a reasonable depth. To further assist the underreaming it is usual to cut the point of the bit blade obliquely as shown in Fig. 42, by which means the bit tends to work away from the centre of the well.

Previous to the introduction of the ex-centric bit, several patterns of underreamers were used, that most extensively favoured being the Austrian underreamer, Fig. 43. By means of this underreamer the drilling and underreaming can be done simultaneously. In strata of ordinary hardness this tool works satisfactorily, but it is not reliable in extra-hard ground, as the cutters tend to close, owing to the tension-spring being too weak to keep them in one position, and immediately the cutters close, the hole becomes conical, and eventually prevents the free passage of the tools.

The tool joints used with the pole system are conical and resemble those of cable tools, the only difference being in the length of the pins, which on the pole tools are much shorter, and should in all cases be increased in length for safe working.

Russian Freefall System. The action of these tools, although percussive, is different from other systems in which jars are used, the tools being picked up when the walking-beam is at its lowest point, and released at the top of the stroke. Having a free drop, they naturally force their way downwards in soft ground, and are released only with difficulty, but in a measure this is avoided, as the drilling and underreaming is done simultaneously, and undoubtedly the underreamer cutters, which are very wide, materially help to retard the free drop of the tools.

The set of freefall tools comprises the drilling-bit, underreamer body, drill stem, and freefall, the connection with the surface being made by iron rods, usually about 1¼ inch square in section: the feeding out is done by means of a temper-screw very similar in pattern to that used with the cable tools. The drilling rigs, owing to the great weight of pipe which has to be handled (the initial diameters of wells in the Baku district usually being

about 36 to 40 inches), are very heavy, and differ entirely from the rigs used with other systems.

Owing to the large diameter of the wells, the drilling bits are necessarily very large. Formerly the bits in use were made about 3 to 4 feet in length, but as the strata are very tenacious, it was found that such long bits, when broken off and left in the well, were extremely difficult to move, and during recent years the length of the bits has been considerably reduced. It is seldom that the length now exceeds 20 inches. It is questionable if these short bits are easier to recover from the adhering strata than the long bits, but they have reduced the risks of tools being lost, as it is now impossible for the drillings to cake and bridge over between the bit and the underreamer body, as undoubtedly did occur formerly, when the long bits were used.

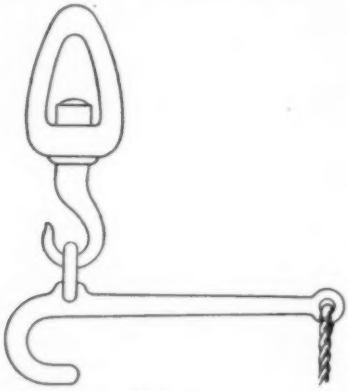


Fig. 44.

In commencing a well with freefall tools, it is usual to start by means of a slip-hook (Fig. 44), which is suspended from the haulage rope. With this appliance, sufficient depth, usually 35 feet, is drilled to permit of the freefall being added to the string of tools. The freefall, Fig. 45, is composed of two separate parts, the rod and the body, held together by means of a wedge which works in vertical slots cut in the sides of the body. The top ends of these slots are recessed sufficiently in depth to permit of the steel wedge entering and resting on a ledge, also made of steel.

In operating the freefall the handles, fixed to the temper-screw,

are held by the driller. On the downward stroke these are pushed forward from right to left, but immediately the downward stroke ends, they are quickly pulled backwards, the steel wedge enters the recess, and the tools are carried to the top end of the stroke, where, by a quick forward jerk, the wedge is thrown clear from the recess, and permits them to drop freely. The resulting drop is absolutely free, and the bit is driven into the strata by the momentum of the weighty string of tools. Fortunately, as already stated, the underreamer knives partly act as a brake, and this prevents the bit being forced too deep into the rock, as otherwise it would be freed only with great difficulty. No doubt many of the serious fishing accidents which occur are caused through the bit plunging deeply into soft strata: and in attempts to free it the freefall wedge breaks, and the drilling tools are left in the well—to be recovered, in the majority of cases, only after a long period of fishing with heavy fishing rods.

From the foregoing it will readily be understood that the throwing of the freefall is very arduous and tiring work—work which drillers on other systems are not called upon to endure, and it is to the credit of the Baku workman that he has been able, by patience and perseverance, to complete the vast number of wells which exist in the Baku district, by means of a drilling system which in operation requires such an amount of hard manual labour.

It is regrettable that such an antiquated and unwieldy system is considered the only one whereby wells can be completed in the Caucasian oilfields. That the strata to be drilled through are extremely difficult will be admitted by all who have had practical experience on these fields, but this should not condemn all other systems as unsuitable. Many attempts have been made to introduce more up-to-date plant, but all such attempts have failed through being handicapped in one way or another. In many cases the suppliers of the plant have been to blame, in furnishing plant and tools much too light for the work to be undertaken, or else incompetent and inexperienced men have been put in charge of the work, where the conditions demanded men who were not only thoroughly experienced in the various well-engineering difficulties met in the Baku and other oilfields, but also thoroughly conversant with the particular drilling system which was being tested. On the other hand it must be admitted that the open antagonism shown by the local administrators and employees has frequently condemned new tools even before they have been tested.

The majority of the local engineers, although highly trained in the theory of mining and engineering generally, lack the great essential of a thorough practical training in well-drilling work, with the result that when accidents occur the manager has to rely on the information given to him by the driller, who frequently is left to his own initiative to overcome the difficulty as best he can. This does not refer to the drilling contractors, who as a rule are men who have had long experience as drillers, but they also are always reluctant to break away from old ideas, even improvements on the freefall system being difficult to introduce. The real cause of this conservatism and lack of initiative is not far to seek, and is brought about by the plentiful supply of cheap labour, which, although very ignorant, is, as already stated, very patient and persevering. Undoubtedly if labour-conditions were similar to those met with in other countries, the local engineer, through his thorough theoretical training, would have ere now introduced means to improve and expedite the work.

DISCUSSION.

The President said he was afraid it must be frankly admitted that a large amount of British capital was continuously being wasted through failure to recognise the importance of the principles which the author had enunciated in his paper. Directors of oil Companies and, he thought he must also add, in certain instances, field managers themselves, did not recognise how much depended upon the skill of the operators or upon the high quality of the plant employed. If an endeavour was made to realise what was necessarily involved in drilling a hole a few inches in diameter to a depth of, it might be, more than a mile, he thought it would then very clearly be seen that the operation was difficult enough if all the conditions were exceptionally good, if high skill was employed and the best plant; but they were courting disaster, as the author had said, if an attempt were made to carry out an operation of that kind when those very necessary conditions did not exist. And if that was the case in regard to the drilling of wells, still more was it so in regard to fishing operations, which were occasionally necessary even when the highest skill and the best plant were used. It had always seemed to him, when he had witnessed fishing operations in progress in oil fields in various parts of the world, that there was needed on the part of the operator in such work something very like the innate, unteachable delicacy of touch

which made the skilful surgeon. He was sure the members would recognise that the paper was of exceptional value because the author's statements were thoroughly practical; they were the outcome of his personal experience in work of that kind, and if they led to a better recognition of the importance of high skill and good plant in the carrying out of the work he was quite sure the author would feel very amply repaid for his effort. There were several members present who could with advantage take part in the discussion, and he first of all asked Mr. John Wells, who the members would remember had dealt with certain aspects of the question of oil-well engineering on a former occasion, to open the discussion.

Mr. John Wells said the supposition that drilling machinery might be used in such a manner as to leave no doubts as to the value of a mining property was, he feared, rather a stretch of the imagination, and although with certain classes of deposits the drill was of inestimable value, there were many known cases where results obtained by drilling had been misleading, and not only misleading, but extremely costly.

He agreed with the author that drilling work as undertaken to-day was extremely arduous, but on the other hand the heaviness of the work was almost entirely due to the crude appliances and apparatus common to a branch of engineering in which a sensible use of mechanical skill and appliances might relieve the driller of practically the whole of the heavy work. As a concrete example, he might take the ordinary pattern of drilling rig of the Canadian type, in which one might observe the operator exercising the utmost amount of brute force, either on his brake-lever or on his belt-lever, owing to bad design in regard to the brakes and the leverage obtainable. In a properly-designed drilling apparatus it should be possible to run in the tools, or pull the same out, with two fingers, and he had demonstrated to the drillers in a rig, after redesigning the brakes, that it was possible to run in a string of heavy tools with a piece of thread attached to the lever and held by the operator between his fingers.

Accidents in drilling operations were undoubtedly due in part to inexperience or carelessness of the drillers, but to his mind that was not the crux of the question, and he was strongly of opinion that the greater number of accidents were due more particularly to poor material and poor design, coupled with a lack of mechanical engineering training among the drilling staff. For example, what was the use of the average driller with no mechanical knowledge

making a careful inspection of his tools before lowering them into the hole? For, unless the driller was possessed of some considerable knowledge of the strength of materials, it was difficult, if not impossible, for him to judge as to whether the condition of the implements was sound or unsound. Carelessness as attributable to the ordinary driller was as much a fault of the management as of the driller, and he would call attention to the ordinary boremaster's log sheet, which was of the briefest, and normally made up at the end of the shift, whereas, for a proper system of control, all details should be entered in the log as they occurred.

The author drew attention to the purchasing of supplies being left to an agent or clerk, and suggested that this should be delegated to some person or other with a practical knowledge of requirements. If such an arrangement could be made, he felt certain that the percentage of failures would be very greatly reduced, but at the same time it was impossible to get away from the facts that the men available at the present time, capable of selecting and passing the class of tools requisite, were extremely limited in number, and that such men commanded salaries in the field far in excess of what the ordinary Company Director was prepared to pay for an individual whose employment would be limited to a comparatively small percentage of his total available working day.

A cheap tool might be a good investment under conditions wherein there was no difficulty in replacing it if it failed. The same implement, however, sent to a distant location might prove costly to the tune of many hundreds of pounds. One of the difficulties experienced in minutely examining the ordinary drilling rig at stated intervals throughout the twenty-four hours was the dirt and confusion. Admittedly drilling, especially when oil was struck or when using mud flush, was rather a dirty undertaking; at the same time most drilling rigs and machinery were maintained in an unnecessarily dirty condition, and no doubt a large number of accidents were due to the dirty condition maintained.

He very much doubted if the average suppliers of drilling tools would supply exact dimensioned drawings of all tools, plant and accessories which they supplied; in fact, the majority of manufacturers objected strongly. That difficulty, however, was quite easily got over in the field, as each new tool on arrival could be given its field number, and a drawing made thereof with full details of dimensions and gauge of threads, etc. With further reference to the marking and recording of tools, it was very necessary that individual strings of tools should be maintained, when possible,

as collective or unit strings. Thus, a set of tools, for instance, run in a 10 inch casing, comprising swivel, jar, bars and bits, should not be indiscriminately mixed with other strings, as a particular set of tools got a thread-setting or joint-setting of its own, and it was seldom that other joints could be employed without having to be fitted to suit the string in which they were to be comprised.

It appeared to him that there was a grave tendency to stick on weight in drilling tools in order to obtain strength, and in many cases that was undoubtedly a false economy. He did not think sufficient advantage was taken of the higher grades and special grades of steel, such as were used in other branches of engineering, to obtain strength combined with lightness. As a special example of undue weight one might note the ordinary standard box in tool-joints, in which the box was made unduly heavy and thick in order to obtain what the driller called "a good joint." After a long series of breakages of pins on standard tool-joints, he had the whole of the boxes turned down, and the faces, where the bits shouldered, reduced to 80 per cent. of the area of the pin at its base. As a result of doing that they ran for nineteen months without ever having a joint break in the hole; previously scarcely a week passed by without at least one broken joint.

He had a heartfelt sympathy with the author on the difficulties of the geologist in relation to probable depth. Equally he might extend his sympathy to the average consulting engineer, himself among them, and the directors of Companies, who were asked to believe in the capacity of plants as specified by the manufacturers. At the same time, in common fairness to the manufacturer, one must admit that circumstances in drilling were extremely variable, and where in good formations a plant might be strong enough for 3,000 ft., there were other circumstances wherein the plant would be absolutely useless for even 1,000 ft. of drilling. However, both directors and consulting engineers clamoured for cheapness in first cost, invariably blinding themselves to the fact that initial cost in machinery or important engineering works bore but a small proportion to the ultimate cost.

He wished to draw special attention to an omission in the paper, namely, that of casing. The most powerful and most perfect of drilling machines might be adopted and used, but if the casing strengths were on the light side, then, despite the advantages arranged for in the machinery, the weak casing would defeat the efforts. On the question of casing he thought much might be done by the Institution by creating a standard, and as a suggestion he ventured to submit a table of casings with a formula which

TABLE SHOWING THICKNESS OF SHELL OF CASINGS FOR DEPTHS TO 5000 FT.

Outside Diameter in Inches.		LENGTH OF STRING OF CASING IN FEET.																				
		500.		1000.		1500.		2000.		2500.		3000.		3500.		4000.		4500.		5000.		
		T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	
20 in.		0·42	86·00																			
18 ,,		0·38	68·30	0·47	85·90																	
16 ,,		0·34	55·70	0·42	68·70																	
14 ,,		0·29	42·00	0·36	52·10	0·43	62·00															
12 ,,		0·25	30·76	0·31	38·00	0·37	45·65	0·43	52·00	A												
		0·27	33·10	0·35	42·68	0·43	52·00	0·51	61·00	B												
10¼ ,,		0·22	23·28	0·27	28·70	0·32	32·60	0·37	38·78	0·42	43·05	A										
		0·23	24·30	0·30	31·26	0·37	38·80	0·44	46·20	0·51	51·60	B										
8¼ ,,		0·18	15·70	0·22	19·10	0·26	22·10	0·31	26·79	0·35	29·96	0·39	33·25	A								
		0·19	16·70	0·25	21·60	0·31	26·80	0·36	30·68	0·42	36·06	0·48	39·40	B								
7 ,,		0·15	10·75	0·18	12·62	0·21	15·00	0·25	17·67	0·29	20·30	0·32	22·30	0·36	25·11	A						
		0·16	11·46	0·21	15·00	0·25	17·70	0·30	21·05	0·35	24·36	0·39	27·00	0·44	30·14	B						
6½ ,,		0·14	9·50	0·17	11·00	0·20	13·32	0·23	15·20	0·27	17·90	0·30	19·48	0·33	21·40	0·36	23·20	A				
		0·15	9·90	0·19	12·50	0·23	15·20	0·28	18·60	0·32	20·65	0·36	23·20	0·41	26·00	0·45	28·27	B				
5 ,,		0·11	5·91	0·13	6·56	0·15	7·62	0·18	8·99	0·21	10·60	0·23	11·57	0·26	12·90	0·28	13·99	0·31	15·34	A		
		0·11	5·91	0·15	7·62	0·18	9·00	0·21	10·60	0·25	12·44	0·28	14·00	0·31	15·34	0·35	17·03	0·38	18·39	B		
4½ ,,		0·10	4·77	0·12	5·72	0·14	6·56	0·16	7·27	0·19	8·66	0·21	9·50	0·23	10·36	0·25	11·12	0·27	12·10	0·30	13·19	A
		0·10	4·77	0·13	6·00	0·16	7·27	0·19	8·66	0·22	9·80	0·25	11·13	0·28	12·40	0·31	13·70	0·34	14·80	0·36	15·70	B

LENGTH OF STRING OF CASING IN FEET.

Outside Diameter in Inches.		500.		1000.		1500.		2000.		2500.		3000.		3500.		4000.		4500.		5000.		
		T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	T.	W.	
10½ in.		0·22	23·84	0·28	30·00	0·33	35·00	0·38	40·00	0·44	46·50	A										
		0·24	25·00	0·31	33·30	0·38	39·79	0·45	47·53	0·51	53·33	B										
10 ,,		0·21	21·63	0·26	26·50	0 31	31·70	0·36	36·83	0·41	42·18	A										
		0·23	23·50	0·29	29·50	0·36	36·98	0·43	43·12	0·49	48·48	B										
9 ,,		0·19	17·70	0·24	22·20	0·28	25·60	0·32	29·00	0·38	34·00	0·42	38·00	A								
		0·20	18·60	0·26	23·80	0·32	29·02	0·38	34·21	0·44	39·61	0·50	44·51	B								
8 ,,		0·17	14·00	0·21	17·29	0·25	20·29	0·29	23·70	0·34	27·50	0·37	29·50	0·42	33·70	A						
		0·18	14·70	0·23	18·80	0·29	23·31	0·34	27·11	0·39	31·36	0·45	35·73	0·50	39·27	B						
6 ,,		0·13	8·10	0·16	9·78	0·19	11·60	0·21	12·80	0·25	15·05	0·28	17·00	0·31	18·60	0·33	19·60	A				
		0·14	8·50	0·18	11·00	0·22	13·45	0·26	15·69	0·29	17·34	0·34	20·30	0·38	22·11	0·42	24·75	B				
5½ ,,		0·11	6·10	0·14	7·60	0·16	8·30	0·19	10·00	0·22	11·60	0·24	12·60	0·27	14·00	0·29	15·00	0·33	17·10	A		
		0·12	6·47	0·15	8·00	0·19	10·17	0·22	11·68	0·26	13·49	0·29	15·07	0·33	17·00	0·36	18·31	0·40	20·24	B		
4 ,,		0·08	3·45	0·10	4·00	0·12	4·87	0·14	5·50	0·17	7·00	0·19	7·65	0·20	7·76	0·22	8·71	0·24	9·50	0·27	10·70	A
		0·09	3·85	0·12	4·90	0·14	5·81	0·17	7·00	0·20	8·05	0·22	8·76	0·25	9·81	0·28	10·90	0·30	11·62	0·33	12·62	B
3½ ,,						0 10	3·40	0·12	3·90	0·14	4·60	0·15	4·70	0·17	5·60	0·18	6·00	0·20	6·40	0·22	7 00	A
						0·12	3·90	0·14	4·60	0·16	5·18	0·18	5·90	0·20	6·44	0·22	7·04	0·25	7·85	0·27	8·50	B
3 ,,						0·09	2·80	0·11	3·30	0·13	3·90	0·14	4·20	0·15	4·46	0·17	5·10	0·18	5·30	0·20	5·90	A
						0·11	3·50	0·13	3·90	0·15	4·46	0·17	5·00	0·19	5·64	0·21	6·18	0·23	6·70	0·25	7·20	B

although empirical, was based on data from many quarters of the earth in which drilling was undertaken. For this table, pp. .., .., the formula used was $T = \frac{(P F + 1386)}{86670} D$, where T = thickness of casing in inches: D, depth in feet: P, hydraulic pressure at different depths + one third: F, factor of safety, being A 1·5, B 2: and W, weight per foot in lbs.

Each particular Company had its own Specification, its peculiarities of diameter, thickness, threads, length of collar, length of thread, etc. In the United States of America, casings had become more or less standardised to meet the circumstances of different fields, but the fact remained that many English manufacturers of casing were turning out a great variety of casing to special specifications, whereas a standard specification for certain conditions and circumstances would be beneficial to the profession as a whole, both in regard to cost and simplicity.

As ordinarily understood, the diamond crown represented an extremely expensive item in drilling, and many were under the impression that the diamond crown was confined in usage to crowns of from 1½ to 3½ or even 6 inches in diameter. As a matter of fact, diamond crowns were perfectly possible, and indeed were in use, up to diameters of 10 and 12 inches, but, in place of being set with fine diamonds, were set with the cheap class of "bort" or "carbonado;" such diamond crowns of 12 inches diameter would not exceed 28*l.* to 30*l.* in cost, and would be eminently suitable for drilling soft sandstones, moderately soft shales, gypsum and salt. He noticed that one of the good points of the Calyx drill had been omitted, namely, the fact that the Calyx people used a straight-edged tooth, whereas the majority of tooth cutters had inclined teeth, with the result that after a minimum amount of wear, the teeth presented a maximum of surface, and in consequence the average tooth crown was only a cutting agent for a minimum of its life. He disagreed with the author in his statement that when drilling with chilled shot the speed was approximately the same as with the diamond crown. As a matter of fact, although there was no known formula, empirical or otherwise, of the speed at which crowns should travel, there was a vast difference between the rotation-speed of large shot crowns as compared with that of diamond crowns of ordinary diameter in regular use. The failure of chilled shot in soft strata was accounted for by the fact that pressure drove the hard steel shot into the strata, whereas the cutting value of chilled shot was dependent upon its breaking-up capacity, and the consequent

presentation of new cutting edges, and it followed in practice that, by using a softer and more brittle material according to the character of the rock, other things than chilled shot could be used with improved results. For example, chilled cast iron broken up into small fragments was infinitely softer than chilled shot, and with a suitable crown would give results in soft strata proportionately as great as those which could be obtained in hard strata with hard chilled shot. The author mentioned that the shot should be fed automatically, and at a speed corresponding to the requirements of the drill. It would be a matter of great interest, not only to himself but, he felt sure, to all the members of the Institution, if the author would explain how he fed shot automatically; secondly, as to how he correlated that automatic action with the drilling speed; thirdly, the adjustment in hardness of the chilled shot to the strata being cut, and fourthly, the relative speed of drilling.

Under the heading "Rotary" the author remarked that the rotary system was the only system which permitted of drilling to 1,200 ft. or so without using casing in soft strata. That was by no means correct, as the mud-flush percussion system would, under certain circumstances of ground, drill as fast, if not faster, than the rotary, and just as thick a mud could be used as with the rotary. It would have been of interest if the author could have given some figures on the character of clays suitable for muds, as no doubt by the use of a suitable clay a large amount of the wear and tear on the pumps could be avoided.

In diamond drilling an essential feature to success was the control of the weight exercised by the crown on the formation being cut. He noticed that the author drew particular attention to the fact that the tools should not be lowered too fast, and that the best work was done when the drill just touched the bottom of the hole with only sufficient pressure to assist its descent. The ordinary rotary drilling rig had no capacity for fine adjustment other than the slipping of the brake, under which circumstances it was impossible to obtain an even, steady pressure, or a pressure, indeed, which might be varied as necessary according to the character of the formation being drilled. A 6-inch column a couple of thousand feet long would compress under its own weight a matter of 6 to 9 inches, and it was obvious that it required a very nice sense of judgment to shake a brake with sufficient nicety to maintain any desired degree of pressure. It therefore appeared to him that one of the most radical changes required in the ordinary rotary system as at present applied was a proper and effective means of controlling the descent of the column.

The question of control of the return flow was of importance, and it was obvious that on approaching oil that return flow must be under constant observation. Constant observation by the ordinary driller was very liable to result in an occasional glance at the return water, and it seemed to him that it would not be a difficult matter to fix an automatic sampler which could be depended upon to sample the return flow automatically at stated intervals, under which condition it would be possible for one or other of the engineers or geologists to examine at the end of the shift a complete set of samples, and the responsibility of the driller would be lessened and controlled.

He could not help being surprised at the author's statement as to the reasons for the non-success of the wire rope. There was no reason why all the flexibility of the manila rope should not be combined in the wire rope, and as for the difficulty of the rope breaking at the socket, that was entirely due to the use of the wrong type of rope. Of course it was obvious that ropes would break at that point in time, but as a general rule, with a suitable wire rope the breakages at that point should not occur, and the rope should never be allowed to get into such a state that it was liable to break in the hole. The cutting off and resetting of a rope into the drilling swivel was a matter which could be done quite easily in a couple of hours by any competent driller.

The dressing of bits with a concave edge, as suggested by the author, might be satisfactory in soft formations, but in hard formations he could not imagine a worse system. Firstly, there was a certain difficulty in dressing the bits; secondly, there were grave difficulties in the way of tempering such bits; and thirdly, bits of that type did not keep the detritus or cutting in motion so well as those bits possessing a rounded edge. In metalliferous mining it had been found that bits with a well-rounded edge, i.e. convex as opposed to concave, could be depended upon to cut 20 to 30 per cent. more ground without redressing than would a straight chisel bit, or a concave one as suggested by the author. The tendency to increase the length of drilling bits without a proportionate increase in the length of shank not only increased the prospect of breaking of pins, but greatly increased the difficulties of fishing, and many of the long modern-day bits were made with shanks so short that in the event of breakage of the pin it was almost impossible to get any form of fishing socket over what remained of the shank.

The author drew attention to the necessity of polishing the faces of the shoulder and box, in order to obtain a better friction

hold. Undoubtedly a good surface was essential, but an infinitely more important matter than the polishing of the surfaces was that the surfaces should approach each other parallel. If any member of the Institution would take a carefully prepared pin and box with a taper pin, or, indeed, with a parallel pin, he would find that if the tools were screwed home gently by hand, one side would be touching, and the other side would be open, sufficiently at least to show daylight between the surfaces, and it would be obvious that to bring those two surfaces together pressure would have to be exerted, with a tendency to wrench either the pin out of vertical, or the box out of shape. The most frequent cause of trouble with the screwed joint was undoubtedly due to the fact that it was impossible to bring two surfaces together absolutely parallel by means of a screw. From observations and trial he had found that the best result was obtained by reducing the area of the faces to 80 per cent. of the total area of the base of the pin. That meant a considerable reduction in the strength of the walls of the boxes, but with steel boxes and steel pins that was no defect, and by micrometer measurements it would be found that the boxes gave very slightly, and under the circumstances, if the threads were properly fitted, a good friction hold was obtained both on the threads and on the faces of the shoulder.

The author made the statement that drilling with poles was simpler and required less skilled labour than drilling with a wire rope. In that he could not agree with him, and the disadvantages of poles, especially in shallow holes, as compared with a cable, were exemplified in practice. Taking a particular instance in which poles were being used by a pole driller having twenty years' experience, and making from 18 inches to 2 feet per shift, a cable was substituted for the poles, and the same driller then quite comfortably made 11 to 12 feet per shift, despite the fact that he had never used a cable before, and strongly objected to being made to use one.

Mr. F. G. Rappoport thought that one of the most important points which the author had introduced in his paper was the training of engineers for the arduous duty of oil-well engineering. He was specially pleased at the fact that the author had called his paper "Oil-Well Engineering," because the fact was often lost sight of that the drilling of an oil well was essentially an engineering proposition. Many people seemed to think it was merely a question of some form of skilled labour, but it was very far from being only that. It was one demanding the highest

engineering capabilities and training, and in the matter of training men for such duties, he would go even further than the author of the paper had suggested. Mr. Calder had stated that an engineer should have at least two years' practical training on an oilfield. Personally he would make the prospective oil-well engineer go through a proper course of mechanical engineering training in the way in which mechanical engineers were being trained at the present day, i.e. combining both the theoretical and the practical side of the work. Many of the colleges and of the great institutions of the country had taken up the matter of training for particular branches of engineering, and no doubt in time their own Institution would deal with this question as far as concerned Oil Technology, and carry it to a successful conclusion. An oilfield was a great engineering concern, and therefore the man at the head of affairs should be essentially an engineer of experience. The author had drawn attention to many of the points which showed the necessity for a man of that ability and training being at the head of affairs,—points such as the standardisation and the examination of tools, and so on, matters which could only be appreciated and dealt with by an engineer. A very excellent summary had been given in the paper of the various drilling methods and systems at present in use. He thought the author, however, had made a slight mistake in saying that the freefall system was the only system being used on the Caucasian oil fields. He presumed he meant the Baku oilfield, where the system was introduced at a very early period of its history. It was rather an interesting object lesson that on three oilfields of Russia,—Baku, Grozni and Maikop,—three distinct systems were now being used, i.e. in Baku, the freefall system; in Grozni, cable tools almost exclusively; and in Maikop, the Galician or Canadian pole system. He agreed with the author that the freefall system was a most cumbersome and unwieldy apparatus. It had, however, grown up with the conditions existing on the Baku oilfield, and one could perhaps sympathise somewhat with the Baku engineers and operators in their difficulties in breaking away from it. After all, many hundreds of wells were being drilled by that system, and it was not such an easy matter to scrap a system wholesale and introduce a new one. At the same time, there was no doubt that the freefall system was more or less doomed with the increase in depth of the wells, which was now going on in the Baku field. The manual labour and time absorbed in throwing off the freefall naturally increased with the depth, reducing the speed of drilling. The freefall system further caused great expense in every department.

The depths drilled were at a time small, necessitating frequent removal of tools, and consequent waste of time. Each column of casing could only go to a certain depth, and naturally as depths increased the initial diameters had to be greater and greater, which enhanced the expense all round. It was therefore only a question of time before this system would become impossible, as depths increased. In fact the signs of the times were already visible in that field, where attempts were being made at the present time to introduce other quicker and more economical methods of drilling.

In dealing with the rotary system, the author had mentioned speeds of 75 and 100 ft. per day. The speaker had personally seen in the Ilskaya oil field a rotary work at an average of 126 ft. a day, i.e. 1260 ft. were drilled in 20 days; working, half time, i.e. one shift which worked out at about 126 ft. a day. He thought that stated the case pretty well for the rotary system in a country where this system was an entirely new one.

Mr. M. Ockenden asked the author what he considered the most suitable plant for prospecting in an absolutely new area. It was very difficult to draw up a Specification from the meagre information that was usually given when an estimate was required for the cost of the preliminary plant. Sometimes the depth was given, and sometimes it was not. If the maximum depth was given, even then it was necessary to guess at the diameter and the style of casing to be used, which was governed to some extent by the system of tools employed. He was rather inclined to think from what was stated in the paper that the author would favour a combination plant, but he did not quite understand how geological results could be obtained when a rotary system was employed, which would be an auxiliary, he took it, in overcoming any difficulty that might be met with.

The question of the pipe was a very serious one, and, like many others present, he would like to see some standardisation adopted. Standard sizes of pipe would have to be made for the different styles of drilling. He believed he was right in saying that the Californian field had evolved a kind of casing which would permit of slight driving, which was almost a combination of a drive-pipe and casing.

In connection with the rotary system, the author had not referred to the disc bits or to the special bits that had been designed for cutting very hard formations. The disc bit was apparently new, and had only been used at present in California, but some

difficulty was being experienced on account of the delicacy with which it had to be used: the drillers were inclined to put too much weight on the stem. He would like to know if the author had had any experience of that form of disc bit, and was acquainted with any of the results that had been published.

He was glad to see that some reference had been made to the chilled shot. He thought more would be heard on that question when certain prejudices had been overcome, as it could undoubtedly be used to advantage in fishing operations, if not in actual drilling.

So far as prospecting plant was concerned, he thought he was right in saying that the early drilling in Trinidad was undertaken by cable-tools, and the slow progress that was made, and the practical failure in some cases to get good results, were due not so much to the plant as to the men. He had heard it stated that drillers who were familiar with the Pennsylvanian strata were employed, and until men were engaged who were familiar with the Californian conditions, and had a knowledge of the casing and how to handle it, no progress was made with the old tools. He would like to know if the author could give any figures of the results obtained from the Californian tools in, say, Trinidad, which was more or less new ground.

Mr. Calder, in reply, said that Mr. Wells had mentioned that of recent years the results of diamond and other core drills had been questioned in mining circles. That was no doubt true where only one well or bore hole had been sunk, but where several had been sunk, thus permitting a triangulation to be made, fairly accurate and conclusive results could be obtained respecting the thickness, dip, etc., of any particular stratum. Furthermore, the cores obtained, unless they were dropped into the well maliciously, could not be anything but true specimens of the ground down below.

He agreed with Mr. Wells' remarks respecting the poor material in the way of plant that engineers had to work with on oil fields. Well-pipe, for instance, was sometimes so hard as to snap at the least blow or twist, or so soft as to be dented or bulged by even a small stone outside it.

Sometimes also the metal of drilling-tools was of poor quality, but still more often, the string was kept too long at work, and became crystallised, requiring in that case to be annealed. If the tools were not attended to, a breakdown and fishing job inevitably resulted. Tools, like everything else, had a limited life of usefulness, and then prolonged use, even with annealing,

risked disaster. Even the best metal deteriorated through friction and magnetisation.

Mr. Wells had broached a subject which interested everyone in the oil industry, namely, the standardisation not only of tools, but of well-pipe. At the present moment there was a vast difference between American and English pipe. His experience of English manufacturers was that a few years ago they quoted the inside diameter, adding weight for any extra thickness outwards. American manufacturers quoted the mean diameter, keeping the outside constant, and adding weight inside by reducing the internal diameter for the smaller gauges. Up to 12 inches the outside diameter was taken, and beyond this, the inside measurement. A few years ago he ordered a certain amount of American pipe, but according to the English method. He discovered his mistake when the first string was received. As a matter of fact, the American manufacturers had asked him if there was no mistake, and thus he learned the difference of method. He understood that all sizes are now quoted by outside diameter, adding weight inside.

He had not referred in his paper to complete drilling units of tools being kept together, for the simple reason that he hoped to bring that subject up in a further paper dealing with fishing. With regard to the speed of shot drilling as against diamond drilling, he thought Mr. Wells and all the other members would agree that in soft ground the diamond drill was not at all suitable and could not compete with the serrated crown. In hard rock, if compact and free from fissures, the speed of the diamond drill exceeded that of shot, but the high cost of the bort made it probable that the diamond drill would eventually be superseded by the serrated shot-armed crown. He admitted, however, that it was possible to use the diamond drill in gypsum, because that material was not sticky like clay.

Mr. Wells said he differed from Mr. Calder's opinion in that respect, because in his experience gypsum was a very sticky material in most places.

Mr. Calder said the little gypsum he had had experience of had not been sticky, but it might not have been true gypsum.

The automatic shot-feeds to which he had referred had been introduced on the latest types of small Calyx plant in the States: he was shown them last year in New York. Their maximum diameter was then about 6 in., but larger diameters had been made since. They were graduated for different hardnesses of strata, and could be altered without stoppage.

With respect to the rotary draw-works, it was a sore point that the only method of regulating the descent of the drill was by the driller sitting on the brake-handle to ease the brake, and let the tools down. There was so far no way known of counterbalancing the rotary drill stem. It was to be hoped that, as the manufacturers had solved the question of damage to drill stems by introducing tool-joints, clamps, etc., they would now improve on the draw-works, a subject to which attention should have been directed long ago. Possibly some type of hydraulic feed might serve, as with the diamond drill.

From the nature of the work, it was impossible to keep the surroundings of a well whilst drilling in a neat and cleanly state, but the superintendent was largely to blame for the chaos and untidiness often seen. All workmen were liable to become negligent unless frequently reminded of their duty by their superiors.

Mr. Rappoport had referred to the use of the freefall in the Caucasus. The speaker had referred in that connection solely to Baku. The cable system now in use at Grozni was of a very old type, the bits were mostly flat, necessitating continual turning of the cable. To permit of this being done in a forward direction, and to avoid back-turning, with possible unscrewing of the tools, it was the custom to cut the cable in lengths which could be quickly wound off and on the bull wheel shaft before and after a run.

A good case had been made out, by Mr. Rappoport for the use of the freefall tools in Baku, viz., in the extraordinary drilling difficulties met with. One of the reasons, and no doubt the principal cause, was brought about by the extraction of the oil from the wells by bailing buckets instead of deep-well pumps. The action of the bailer bucket tended to pick up all loose material in the bottom of the well, and the continual cleaning no doubt caused the strata to cave, such cavings of ground often even extending to the surface. As a result the strata for some considerable distance around the sites of old producing wells was all broken up, and it was his opinion that this had a great deal to do with the slow rate of drilling and the many difficulties met.

By extracting the oil by means of deep-well pumps, such large final diameter of the wells as is necessary for extraction by bailing, would not be required, and this would mean a great reduction in the initial diameters of the well pipe. By this much faster drilling would result, and individual columns of pipe would be carried a great deal deeper than is possible at present. There would thence ensue a saving of capital expenditure all round.

Mr. Ockenden had asked for a specification for plant. There

were different specifications as there were different men. Every engineer had his own ideas, and he (the author) was afraid that what would please him would not suit his neighbour. He had had experience of several oil fields in which he had had to take over the duties of other men. A few years ago he had to visit a place to examine and report to his employers, and found ten different makes of tool-joints on the work, out of which he was supposed to make up a string of tools. His principals were surprised at his condemning the whole lot, and telling them that he could not guarantee satisfactory work unless supplied with absolutely new material. To their remonstrance, "But we have spent so much money in tools and the material is there, why not use it?" He answered that the material was there, but he would not give the price of old iron for it. They nearly sent him back home for such plain speaking, but eventually allowed him to order the new material required, and he supposed that upon consideration of their previous experience they found reason to accept his conclusions.

His experience of the rotary was three or four years old, and dated back to the experimental stage of the various improvements which were now being used. He therefore had no experience of the disc bits or of the hard-measure tools which he believed had been extensively adopted in the sulphur wells of Louisiana, and in some parts of California.

A suitable plant for prospecting would, in his opinion, be a percussive system combined with the water-circulating method, of which he had shown an illustration. That did not entail heavy weights being transported; it did not necessitate heavy drill stems such as were required for the rotary, and it could be put into use in the course of about an hour.

The speeds of the various drilling systems altogether depended on the strata to be drilled. As he had already stated, records had been made with rotary drills in wells under his supervision, of over 100 ft., even over 150 ft., in 24 hours, but only for short periods: the records did not extend over any length of time, for if they did there would soon be no work for drillers. With cable tools he had obtained speeds of 60 ft. and over, per 24 hours from the start to the finish of the well, in wells 1850 ft. deep. The best records with the rotary in adjacent wells thus averaged 45 ft. per 24 hours from start to finish at 2500 ft., but this was without recent improvements. In Pennsylvania, where the ground was very good, and he believed in Oklahoma also, it was not necessary to put down the pipe while the well was being drilled, and better records than 60 ft. per 24 hours from start to finish of

wells had been obtained. His only experience of the Canadian pole tool was with the Galician type worked by Caucasian workmen, and in the case of a 10 inch well 1,000 ft. deep, 25 to 35 ft. per day had been averaged from beginning to end. The men in that district were not so energetic as other men, on account perhaps of the climate, perhaps of insufficient pay.

He desired to point out that the life of the oil industry absolutely depended on its oil wells, and it was regrettable that this vital part received too little serious consideration. He agreed with the President that those in charge of such work should have practical experience of drilling, and not just stand about on the derrick-floor with their hands in their pockets, and in place of being willing to learn, presume to criticize the work.

In conclusion, he desired to thank Messrs. Eastlake and Dalton for the kind assistance they had given him in revising the paper, and Mr. Ockenden, of the Oil-Well Supply Company, for the generous manner in which he had supplied blocks for illustrating the paper, and assisted him in many other ways.

The meeting terminated with a hearty vote of thanks to the author.

Subsequently, **Mr. C. Temple Orme** wrote as follows :—

One thing that occurs to me is that there is a great risk of caving if there is a fishing scrape in a rotary well which has not been cased. Take for example Mr. Calder's remark on page 243, where he mentions that the bit might twist off, leading to fishing.

Then on page 251 he mentions 35 ft. as the correct depth of water. Does this apply also to wells drilled with the Galician Pole system ?

On page 252 he mentions the making of bits of solid cast steel. I understand that the mild steel was welded on so as to provide a tough screw. Surely a cast steel one is more likely to snap off.

On page 253 he mentions driving the casing into swelling clays. This would not be permissible, I imagine, except in the case of using suitable drive-pipe. Ordinary screwed casing, such as that used in Galicia, would hardly stand the blows if they were hard enough to affect the bottom lengths.

On page 254 he mentions that screwed ends of poles should be true to gauge, etc. The ends of the ordinary drilling poles in Galicia are in most cases turned and chased by boys, using the crudest of gauges. With the fishing poles and large screwed joints it is another matter. Considerable trouble is taken with the latter.

Then on page 259 under Percussion Tools he mentions square rods for the Free-fall system. I should like to ask why they use square rods so much in Russia. I should imagine that the rigidity effect would be very little better than in the case of round poles.

C. T. O.

Mr. Calder replied as follows :—

The thick mud standing in any rotary drilled well is sufficient to keep the well sides from caving for a considerable period, ample to extract any lost tools.

With all systems of percussive non-waterflush tools it is advisable to drill with a minimum of water standing in the well, as the drilling is done much quicker and the well-pipe can be carried deeper. European drillers, however, always work with the well full of water, claiming that the latter acts as a cushion, and prevents the poles flogging the pipes and becoming crystallised.

The necks of "all steel bits" are annealed to give them the required toughness.

In Galicia and Rumania the class of well-pipe used is mostly of the inserted-joint type, which cannot be driven in the manner suggested without running the risk of telescoping, but with care it may be pressed down by means of screw-jacks or other suitable means.

In my paper I particularly referred to the screwing of tool-joints, and not pole-joints, but the latter should also be finished with accuracy, as it is only by using properly made tools that accidents can be avoided.

Respecting the use of square rods or poles in the Baku district, the only reason that can be given is that of assisting the driller to clean down quickly any underreaming irregularities from the walls after each drilling run. This is done by lifting and lowering the tools on the haulage rope, the driller meanwhile holding and gradually rotating the tools by means of a long-handled wrench on the square rod or pole.

W. C.

Seventh General Meeting.

The seventh General Meeting of the Session of the Institution of Petroleum Technologists was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C., on Friday Evening, 28th May, 1915, Sir Boverton Redwood, Bart., D.Sc., F.R.S.E., President, occupying the Chair.

The following Members of Council were present:—E. R. Blundstone, Major A. Cooper-Key, Arthur W. Eastlake, T. C. Palmer, Dr. F. Mollwo Perkin, Robert Redwood. A telegram regretting enforced absence was received from Prof. J. Cadman.

The following paper, illustrated by numerous lantern slides, was read:—

The Evolution of the Oil Tank-Ship.

By Herbert Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A., *Member.*

When I was honoured by an invitation to present a paper dealing with the development of the Oil Tank Steamer, it at once occurred to me that, as so much had already been written on this subject, it would be difficult to avoid traversing old ground. I trust however that I may be able to set out some points in connection with the earlier vessels, and possibly some details of construction introduced in the latest ships, which may be of interest to the Institution.

In no other branch of commercial transport has there been such a radical change as that which was inaugurated by the introduction of the bulk oil-carrier.

Previously practically the whole of the transport of oil had been carried out by the employment of wooden barrels, and of tins contained in wooden cases, the contents of the latter being generally described as case oil. The advent of the bulk oil-carrier abolished this method of transport, and enabled cargoes to be loaded and discharged more expeditiously, at the same time saving the expense of the package. Moreover in a barrel cargo about a sixth of the total weight was represented by the barrels alone.

Immediately the safe transport of petroleum in bulk was assured, this method of shipment was rapidly adopted. In 1885 about 200,000,000 gallons of petroleum was exported from America in barrels or tins, and about 1,750,000 gallons in bulk, but in 1896 the shipments in barrels fell to about 1,700,000 gallons, and the transport in bulk had risen to 484,000,000 gallons.

Although there is no written history of the earliest bulk oil-carrier, the Chinese Newchwang junk, originally built for the carriage of water in bulk, and afterwards used for oil, must be amongst the earliest examples of this class of vessel. It will be observed that the Chinese junk is provided with an expansion-trunk, the object of this, as in the modern steamer, being to allow for expansion of oil by rise of temperature, and also to keep the main hold always full, the wash of oil from the movement of the vessel being confined to a limited space about a third of the beam.

At the same time there is a record that special instructions were issued as to the carriage of oil up the Volga about the year 1723, and in 1754 the Persians collected oil on Holy Island (near Baku), and conveyed it in sailing vessels, evidently in bulk, as it is mentioned that the sea was sometimes covered with oil for leagues, owing to the leaky state of the vessels. It is curious to note that in the early days wooden barges were employed on the Volga to carry oil in bulk, direct to the skin of the vessel, but great difficulty was experienced in keeping these tight, and considerable losses from leakage were experienced. An interesting method, adopted to reduce this loss, consisted in loading the barges when full of oil with a deck-load of stones. This gave the barge a greater draught, and thereby caused the pressure of water outside to be greater than the pressure of oil inside, the balance of pressure being in favour of water entering the barge, instead of oil leaking out, and as the decks were kept low, and the hatches were made oil-tight, this did not allow much water to enter.

Although these earlier examples of bulk oil carriage are mentioned, it was in 1875 that the first organized attempt to transport petroleum in bulk without the use of tanks was made by Nobel on the Caspian: he appears to have loaded a wooden barge with residuum, and despatched it from Baku to Astrakhan. The venture was successful, the leakage being much less than was expected, and the saving in time of loading and discharge was an immense advantage gained. But it was not until 1878 that the first steamship, the "Zoroaster," was adapted for carrying oil in bulk: at first tanks were fitted in the holds, but later on these were removed, and the oil carried to the skin of the ship. It is interesting to note, in connection with some modern vessels to be mentioned later, that these tanks were cylindrical in form, and were placed in a vertical position.

The slide shows a section of the type of wooden sailing vessel employed at the time the steam-tanker made its appearance on the Caspian; it will be noticed that a longitudinal bulkhead is

fitted, but apparently no expansion-trunk was provided, nor any means of keeping holds absolutely full.

During the next ten years over 30 steamers were commissioned for carrying petroleum in bulk on the Caspian, and there is now a very large fleet of steamers engaged in this trade, all burning liquid fuel.

It may be well at this stage briefly to mention the steps by which the present tanker has been evolved. These may be stated as follows:—

(1) The introduction of longitudinal and transverse bulkheads. The functions performed by these structures consist, in the former, of reducing by half the difference in level of oil due to rolling or list of the vessel, thereby preserving the stability of the ship, and in the latter, in reducing the length in which the oil can surge when the vessel is pitching in a seaway. The longitudinal bulkhead was at first only fitted as a divisional washplate, but is now made oil-tight, and of a strength to support the pressure of the total head of oil on either side.

(2) The fitting of expansion-trunkways. These are of a reduced breadth, generally being about a third of the beam of the vessel. The longitudinal bulkhead being carried up to the top of the trunks further reduces the difference in levels of oil due to rolling or listing of the ship, and also provides for the expansion or contraction of the oil by variations in temperature. For this purpose 2 % of cargo capacity is generally allowed. The level of the oil in the trunkways should never be allowed to fall below that of the deck. The introduction of the longitudinal bulkheads reduces by one quarter the loss of metacentric height due to movement of the oil.

(3) The provision of cofferdams forward and aft of cargo tanks. These consist of spaces generally about 4 feet in length, kept empty, and forming a partition between the tanks and the engine and boiler rooms, aft, and a similar protection between the cargo-tanks and the forehold and the deep tank forward, any leakage from bulkheads being collected in these spaces.

(4) The carriage of oil direct to the skin of the vessel without the use of independent tanks. The fitting of separate tanks with their connections had proved a fruitful cause of trouble from leakage, and also provided confined spaces in which gas could accumulate and become a source of danger.

(5) The abolition of the cellular water-ballast double-bottom below the cargo-tanks. In vessels fitted in the old way, there

was always a difficulty in keeping the top of the ballast-tank tight, and one accident at least is on record as due to oil having found its way from the cargo-tank into the double-bottom.

(6) The building of pump-rooms extending the whole breadth of the vessel, and carried down to the bottom plating of the ship and up to the upper deck. This method, when the pump-room is placed amidships, furnishes another cofferdam, dividing the cargo-tanks into two distinct portions, and when two pump-rooms are fitted, as in large vessels, the cargo-tanks can be divided into three separate groups, affording greater safety from danger of mixing when different classes of oil are carried ; the pumps can also be placed at the lowest point, thus facilitating the drainage of the tanks.

(7) The fitting of compound hatches, to deal with the carriage of cargo other than a liquid one. A larger hatch is provided, furnished with a bolted cover carrying the ordinary oil-tight hatch, the whole being removable when a larger opening is required.

(8) The perfection and elaboration of the pumping arrangements. Double lines of suction-pipes extend the whole length of the cargo-tanks, and carry two suctions on each side of the longitudinal bulkhead in each main tank, whereby oil can be transferred from any one tank to another, and different classes of oil can be discharged without mixing in pipe-lines. The suctions are arranged so that the ship can draw from barges alongside with her own pumps. Several discharges are provided in various positions on deck, including lines for the discharge over the stern and bow if required in port, or for the transfer of oil at sea to another vessel.

(9) The fitting of mechanical ventilation to tanks.

(10) The fitting of steam heating-coils in the cargo-tanks. With the introduction of liquid fuel and heavy viscous classes of oil for road-making, etc., it was found impossible to handle these expeditiously at ordinary temperatures; it therefore became necessary to provide means for heating cargoes in the tanks, a temperature of upwards of 120° Fahr. being required in some cases.

(11) The introduction of liquid fuel in place of coal for the firing of the steam-boilers. This required all bunkers to be constructed oil-tight, and the introduction of pumps, etc., for handling the oil, with special arrangements when low-flash oil is used as fuel.

In 1860 America commenced to ship oil to this country in small quantities, practically samples, and it was not until twenty-six years later that Russia commenced to export oil to Great Britain. The first cargo shipped from America was by the brig "Elizabeth

Watts," of 224 tons, which was safely delivered in London about the end of 1861. This immediately led to further shipments, which in 1864 amounted to 7,666,000 gallons, about a quarter of the total export from America at that time, all the rest being shipped in barrels or tins.

Probably the first vessel designed and built in this country for the carriage of petroleum in bulk was the iron sailing-vessel "Atlantic," which was launched from Messrs. Rogerson's yard at St. Peter's on the Tyne in 1863. Her dimensions were 148 feet in length with 28 ft. 6 in. beam, and a depth of 16 ft. 9 in. This vessel appears to have been fitted with sheet-iron bulkheads, dividing the hold into compartments, and acting as washplates. Unfortunately no records of her career have been found.

A schooner was loaded with petroleum in bulk at Sarnia on the river St. Clair, Canada, in the same year, and despatched via the canals and St. Lawrence, her port of destination being Liverpool, but she was lost in the Gulf of St. Lawrence.

The "Charles" was employed in the transport of crude petroleum from America to Europe between the years 1869 and 1872. She was fitted with 59 iron tanks, stowed in the holds; evidently there was some trouble with leakage, as it is mentioned that salt water was introduced into the tanks to make up for the loss of oil, and keep them full.

The "Joseph Fish," another trader, was struck by lightning in the Atlantic, and burnt, in 1876, this being one of the first serious disasters in connection with the carriage of petroleum at sea.

Up to 1878 oil was shipped from America in vessels as described, and also of course in barrels and tins.

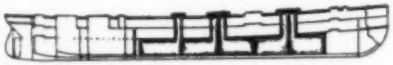


FIG. 46. S.S. "VADERLAND" (2800 t.)

The pioneer tank-steamer built in this country appears to have been the "Vaderland," 2748 tons, launched in 1872 from Messrs. Palmers' yard at Jarrow-on-Tyne. She was fitted with a space of 20 to 26 inches between the tanks and the shell of the vessel, trunkways being carried up to the level of the upper deck.

This vessel was fitted with passenger accommodation, but there is no record that a cargo of oil was ever loaded in her, or in the two sister ships "Nederland" and "Switzerland," built in 1873 and 1874 respectively. It is generally supposed that the owners were afraid that passenger bookings would be affected if it were known

that the ship was carrying petroleum, and it is believed that the tanks were used for water-ballast only. Although it may be claimed that these were the first oil tank-steamers built in this country, they did not solve the problem of the satisfactory carriage of petroleum in bulk.

The first steamer to load a bulk cargo of oil in America, bound East, was the "Stat," owned by Norwegians, and fitted with large tanks, built into the holds. She sailed from Philadelphia for Rouen on October 18th, 1879. This steamer and two sailing vessels, the "Lindernoer" and the "Jan Mayn," traded regularly between America and Rouen for some time, carrying crude petroleum.

The "Fergussons," an ordinary cargo vessel, was in 1885 converted into an oil-carrier by Messrs. Craggs & Sons, of Middlesbro', being fitted with tanks, a tier of which in couples was fitted below and above beams, shaped to conform to the internal moulding of the vessel. Some difficulty was experienced in keeping the connections between the tanks oiltight, but the vessel traded between Batum and Continental ports for about three years, when she was destroyed by an explosion whilst in Rouen. Two separate explosions appear to have taken place, the first shattering a number of tanks, and the second breaking up the hull, and liberating burning petroleum.

In 1886 was launched the first tank-steamer of the type which has been since followed with some modifications and exceptions. She was built, at the suggestion of Mr. Riedemann of Bremen, by Messrs. Armstrongs, to the designs of the late Col. H. J. Swan. She was named the "Glückauf (Good Luck)," and was a vessel of 2307 tons gross register, 300 feet in length × 37 feet beam × 24 feet depth, with a speed of about 11 knots.

Col. Swan's design may be described shortly as follows:—the hull of the vessel was divided into compartments by transverse bulkheads, these compartments being again divided longitudinally by a central bulkhead, which extended through all the oil spaces. A pump-room was provided aft, which extended right across the vessel, and formed a cofferdam or safety-space, dividing the stoke-hold from the oil compartments; between the main and upper decks a narrowed trunk was arranged, the trunkway extending the whole length of the cargo-tanks. The transverse and longitudinal bulkheads being carried up to level of the upper deck, this arrangement allowed for expansion of oil from any rise in temperature, and by keeping the main portion of the tank below the main deck full, reduced the danger of movement of oil from rolling and pitching of the vessel, also providing spaces along the whole length

of vessel on each side of the trunkway for the accommodation of light oil cargoes. The bulkheads were designed to stand the pressure of the full head of oil when one tank was full and the next one empty. A double bottom was fitted, for water-ballast only, under the machinery-space, and in the forehold. The machinery and boilers were placed aft, no tunnel for shafting being required. Although steamers had been built on the Caspian some years before, carrying oil next to the skin of the vessel, it is claimed that the "Glückauf" was the first ocean-going tank-steamer carrying oil in bulk to be constructed on this principle. The expansion-trunkways in this vessel were much narrower than those now generally fitted, being only 4 ft. 6 in. wide on each side of the longitudinal bulkhead. She was fitted with a very long poop, the bunkers being accommodated under this deck and entirely above the upper deck: the spaces alongside the expansion-trunks were not utilized for this purpose, but a portion of this space was designed to carry oil. Electric light was fitted throughout.

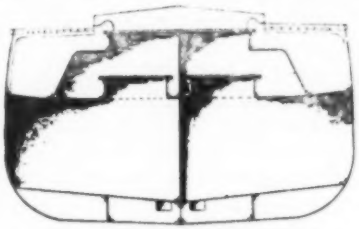


FIG. 47. S.S. "BAKUIN."

In the same year 1885 a tank-steamer, the "Sviet," was built in Gothenburg for the Russian Steam Navigation Company of Odessa. She was 1474 tons net reg. and was fitted with tanks, and in no part was oil carried next to the skin of the ship. For some time it was a disputed point as to whether oil should be carried thus directly to the sides and bottom of the vessel, or should be kept clear of the shell plating, a space being provided between the tanks containing the oil and the sides and bottom of the ship, but it is now generally agreed that, to minimize danger of explosion, all spaces where gas can accumulate should be avoided as far as possible.

The "Bakuin" was built shortly after the "Sviet" in 1886, by Messrs. Gray of Hartlepool, to the order of Mr. Alfred Suart, and presented a compromise between the two systems of oil carrying, a double bottom being fitted, above which the oil was carried to the skin of the vessel up to the main deck; over this a somewhat

complicated arrangement of tanks and expansion-trunks was arranged, the object being to keep the oil above water-line and therefore exposed to the heat of the sun, clear of the ship's side, and also to provide a double tier of expansion-trunks, so that different classes of oil could be carried below and above the main deck. This vessel was the first British-built-and-owned tank-steamer; she traded until 1892, when she was destroyed by fire when in the floating dock at Callao; she was the first vessel built on this principle, which presented many disadvantages and difficulties.

Messrs. Alfred Suart & Co. converted five ordinary cargo ships into oil-carrying vessels, and in addition, between 1886 and 1892, built and managed 11 other bulk oil steamers. The "Era," afterwards the "Apscheron," and the "Oka," afterwards the "Broadmayne," built by Messrs. Palmer of Jarrow-on-Tyne, and the "Charlois," built by Russells of Glasgow, were satisfactory vessels, and have done good work.

The successful running of the specially-built tank-steamer led at once to the building of several vessels whose names have become familiar in the trade, such as the "Elbruz," "Kasbek," "Lux," "Beacon Light," "Lucigen," "Phosphor," "Lumen" and others.

In 1892 Messrs. Craggs of Middlesbro' built the "Henri Reith," a very successful vessel, and one that conformed more to the present-day type than the above-mentioned vessels, having bunkers arranged the whole length of the cargo space on each side of the expansion-trunk; water-ballast also was only fitted forward and aft, and none under the cargo-tanks.

The year 1888 was specially notable for the activity displayed in the building of the new tank-steamers. Messrs. Armstrong alone put out 12 ships. The Anglo-American Oil Company also made its first appearance in London, and commenced the purchase and building of bulk oil-carriers. The first two vessels built to their order were the "Manhattan" and "Bayonne," and these were followed by many notable ships. The "Narragansett," the largest of their fleet, and until lately the largest tanker afloat, was built by Messrs. Scott of Greenock in 1903. In this vessel the machinery and boilers were placed amidships, the screw shafting being carried through an oil-tight tube passing through the after oil compartments; this tunnel was entered from two points by trunkways carried up to the shelter deck. At the time it was considered that a vessel of this size would not prove satisfactory if the engines were placed aft, partly on account of structural questions, and partly as to difficulty in trim under working conditions. These fears have since proved to be

groundless; the advantage of the after position for boilers and machinery being obvious, and the cost of construction less, comparatively few vessels have since been built with engines amidships.

The "Narragansett" is a vessel of 512 feet in length, 63 ft. 4 in. beam, and 32 ft. 6 in. in depth, with a capacity of 11,000 tons of oil in tanks and 1,500 tons of fuel, either coal or oil, in bunkers, her average speed at sea being about 11 knots. At the time of being put into commission she was undoubtedly the finest oil tank-steamer ever built.

Another notable vessel owned by this Company is the "Iroquois," built by Messrs. Harland & Wolff of Belfast in 1907. She was the first tank-steamer to be fitted with twin-screw engines placed aft. She was specially designed to tow a large oil-barge, the "Navahoe," built at the same time for carrying oil across the Atlantic, and has made numerous voyages under these conditions, averaging a speed of about 10¾ knots, and delivering 18,000 tons of oil, including the contents of the barge.

One of the interesting features of this vessel consists in the arrangements made for towing this sea-going barge. A special winch is fitted on the vessel, and another on the barge. The former receives the towing wire on a large barrel, and is so adjusted that, in the event of extra strain being thrown on the wire, a certain amount thereof is paid out, and on the strain being relieved, the winch again takes up the extent paid out, the whole operation being automatic. The winch on the barge acts in the same manner, and originally two cables were used, one made fast on the barge and attached to the winch on the steamer, and the other made fast on the steamer and attached to the winch on the barge, but I believe it has been found in practice that one towing hawser is sufficient. The so-called barge is a vessel of 450 ft. length × 58 ft. 3 in. beam × 31 ft. 2 in. depth, with a gross tonnage of 7718, and is rigged as a three-masted schooner. She is fitted with a steam-boiler and set of pumps in order to deal with her own cargo.

This method of towage transport is adopted to a considerable extent on the American coast.

In 1892 the Shell Transport & Trading Company, under the guidance of Sir Marcus Samuel, commenced operations, and now owns a large fleet. The Company was formed with the object of opening up the Eastern trade, and of the carriage of petroleum in bulk through the Suez Canal, which up to this time had not been allowed, owing to the possible danger arising from a collision and the igniting of escaped oil in a narrow waterway.

The "Murex" was the pioneer vessel of the fleet, built in Hartlepool in 1892, and this vessel was the first to pass through the Suez Canal with a cargo of bulk oil. The building of other vessels rapidly followed, and several cargo steamers were bought and converted into oil-carriers; in 1899, when Borneo began to attract attention as an oil-producing country, new vessels were constructed of increased size.

These vessels were the pioneers in the matter of carrying dual cargoes, and many voyages to the East were made, carrying a cargo of Russian oil outwards, and returning with a perishable general cargo. Large detachable hatches were fitted for this purpose, and a full complement of winches and gear supplied.

These vessels were also among the first ocean-going British vessels to adopt oil as fuel in place of coal, the oil being atomized by a steam jet, and sprayed into the furnaces, a burner patented by Messrs. Rusden Eeles being used.

The "Pectan," built by Messrs. Gray of Hartlepool in 1902, was at that time the largest oil-carrier afloat. The vessels of this Company, now the Anglo-Saxon, established several records, the "Cowrie" being the first vessel burning oil fuel to bring a cargo of oil from Balik Papan to the Thames. Naturally this Company took a prominent part in the discussions in reference to the passage of tank-steamers carrying oil in bulk passing through the Suez Canal. A strong party of British shipowners strongly opposed the granting of permissions to tankers to use this waterway, owing to supposed dangers to other vessels, but their objections were eventually overruled, and, as previously mentioned, in 1892 the "Murex" passed through the canal with a cargo of bulk oil. Previously to this date all oil passing through the Canal had been required to be packed in barrels or cases. At this time the practice of fitting a dividing space or cofferdam forward of the cargo space, as well as aft, was adopted, and vessels are now generally so arranged.

In 1899 the Burmah Oil Company started their fleet of bulk oil-carrying steamers. These were designed to trade entirely abroad, and distribute the Company's oil around the Indian coast. This entailed the establishment of several oil-storage stations for the reception of the bulk oil, as previously the distribution had been carried out by case-oil or barrels. Six vessels were built, the "Syriam," "Kokine," "Khodoung," "Twingone," "Singu," and "Beme," and although not large vessels they were at the time the most complete in their pumping arrangements of any vessel afloat, the pumps on the last-named ship being capable of discharging

400 tons per hour against a pressure of 210 lbs. per square inch. These vessels all burn liquid fuel.

A special design of suction was introduced for dealing with fuel in bunkers, and consisted of a hinged pipe, which could be raised or lowered, and thus draw oil from any level. This overcame the difficulty sometimes experienced when water is found mixed with oil. Whilst the water was settling down to bottom, oil could be drawn from near the surface, and after settlement was complete, the pipe could be lowered to the bottom, and the accumulated water pumped overboard.

Messrs. C. T. Bowring & Co. were amongst the earliest owners who realized the great possibilities of the oil industry, and especially the carriage of oil in bulk. Four years after the "Glückauf" was launched, they commenced the building of their oil fleet with the "Bear Creek," 1890, and since that date have built some 16 vessels; the later ones have been designed specially for the carriage of benzine, the expansion-trunk being carried above the upper deck to the level of the poop and bridge decks, this space providing the extra cubic capacity required, when a light cargo is carried. These vessels are all fitted for burning liquid fuel either on the Howden Wallsend or the Smith Meyer pressure system. It is interesting to note that the "Beacon Light," built in 1890, is still running for this firm, and doing good work. The "Elsinore," commissioned in December, 1913, was sunk by the German cruiser "Leipzic" off the Galapagos Islands in September last.

For some years, vessels carrying 6000 to 7000 tons were favoured by owners, but lately the tendency has been to build larger ships, and in 1912 to 1914, the average was nearer 9000 to 10,000 tons, although ten vessels were built having a capacity of over 15,000 tons each.

There are now about 434 bulk-oil ocean-going steamers afloat, representing a total gross tonnage of 1,637,300, 192 of these vessels being fitted for burning liquid fuel: and as an illustration of the recent rapid increase in numbers, it may be stated that about 50 of these were built between 1880 and 1890, about 98 between 1890 and 1900, 120 between 1900 and 1910, and from and including 1910 to end of 1914 no less than 166 vessels were put into commission, with a total gross tonnage of about 800,000 tons, the output in these five years being equal to nearly half the tonnage now afloat.

In addition to these steam vessels there are 57 sailing ships in commission, representing 99,788 gross tons; only eight of these, totalling 14,587 tons, have been built within the last five years

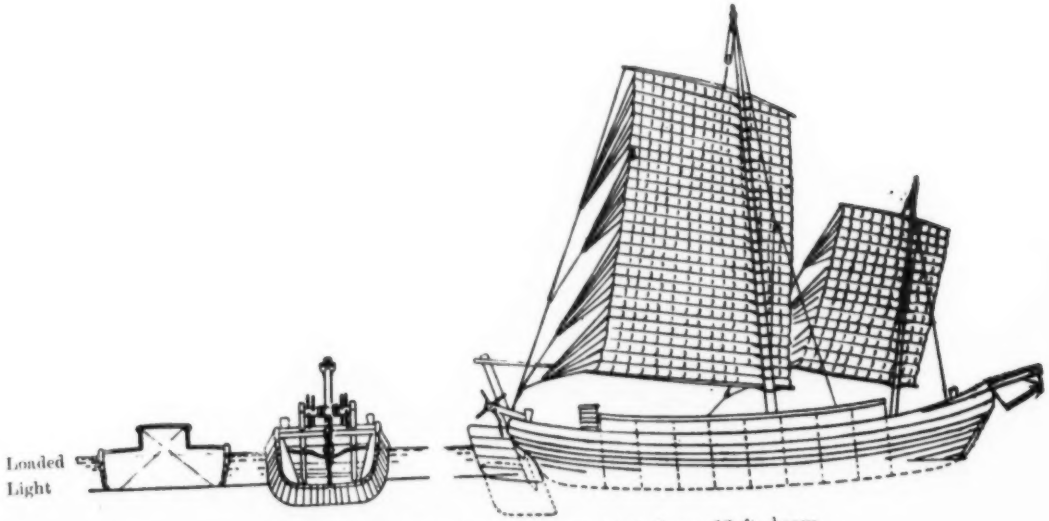


Fig. 48.—Newchwang Junk: 55 ft. long, 13 ft. beam.

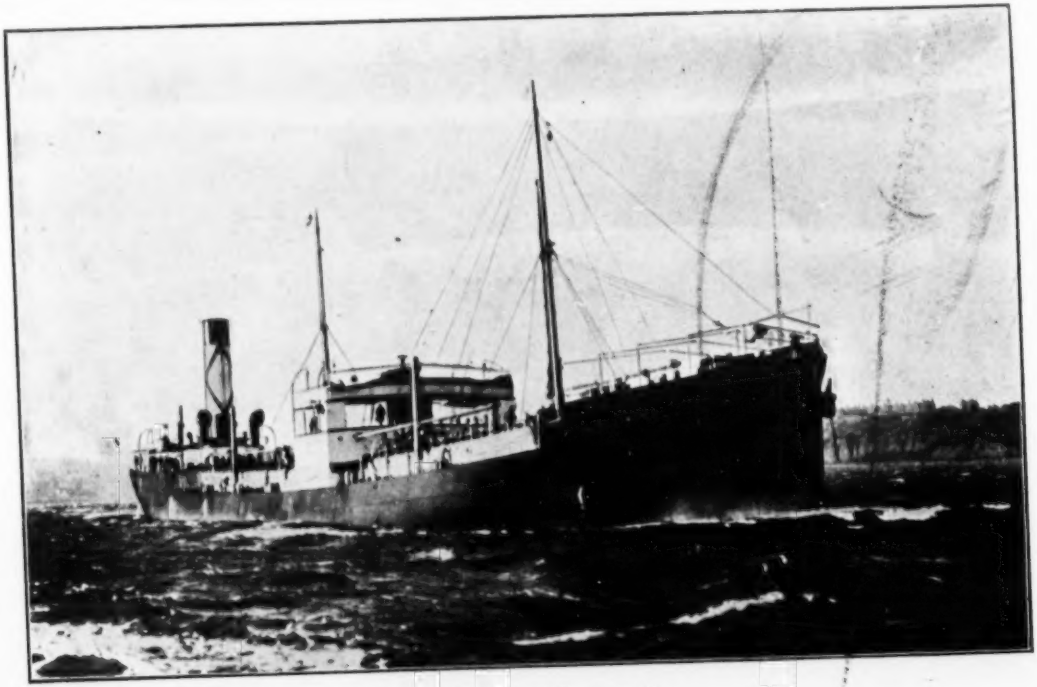


FIG. 49.—S.S. "ELSINORE."

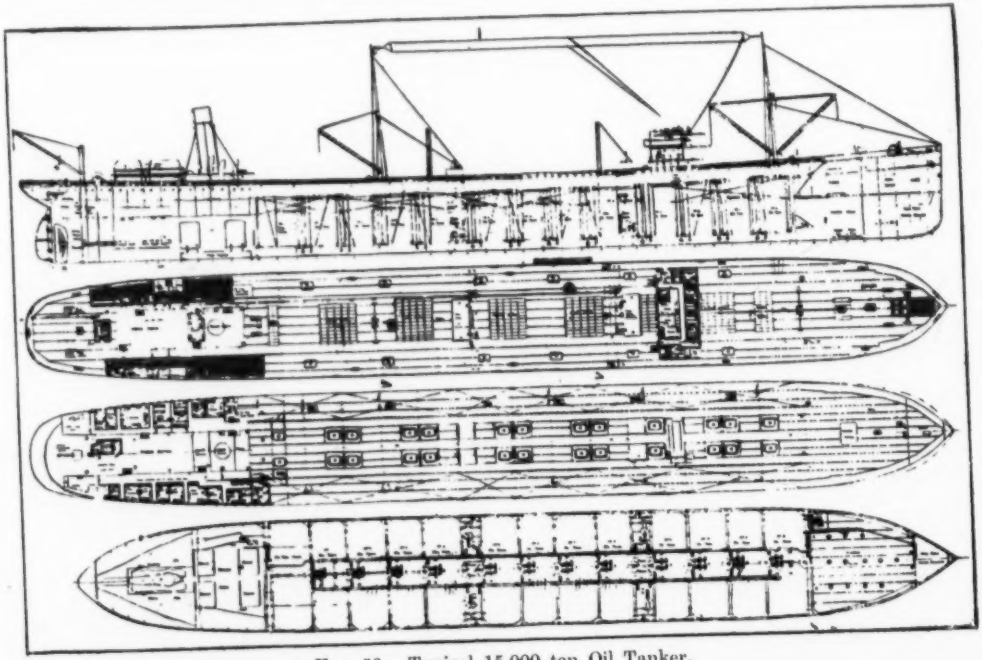


FIG. 50.—Typical 15,000 ton Oil Tanker.

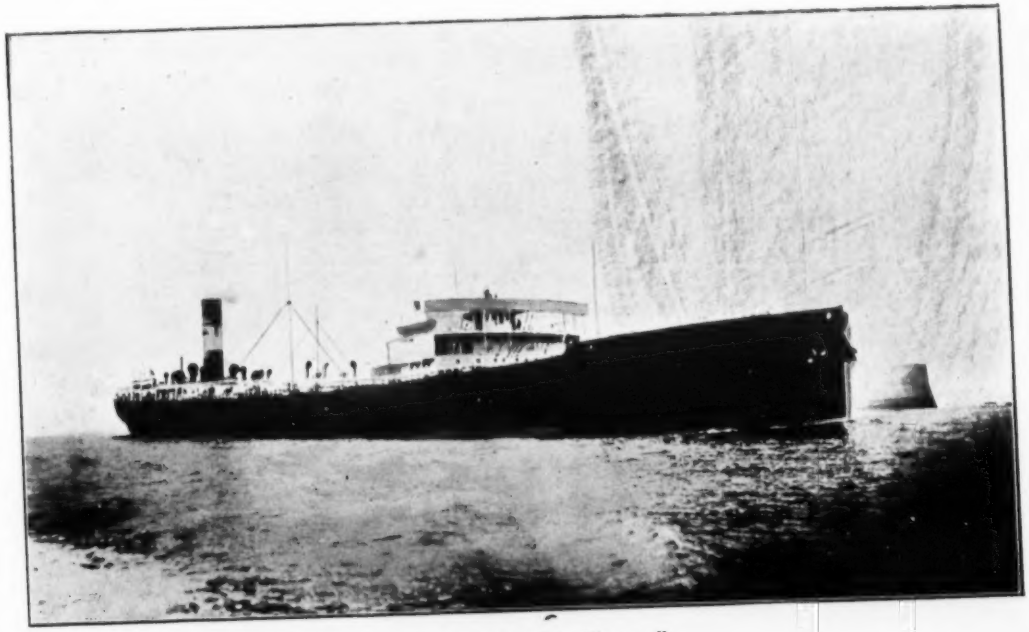


FIG. 51.—S.S. "SAN MELITO."

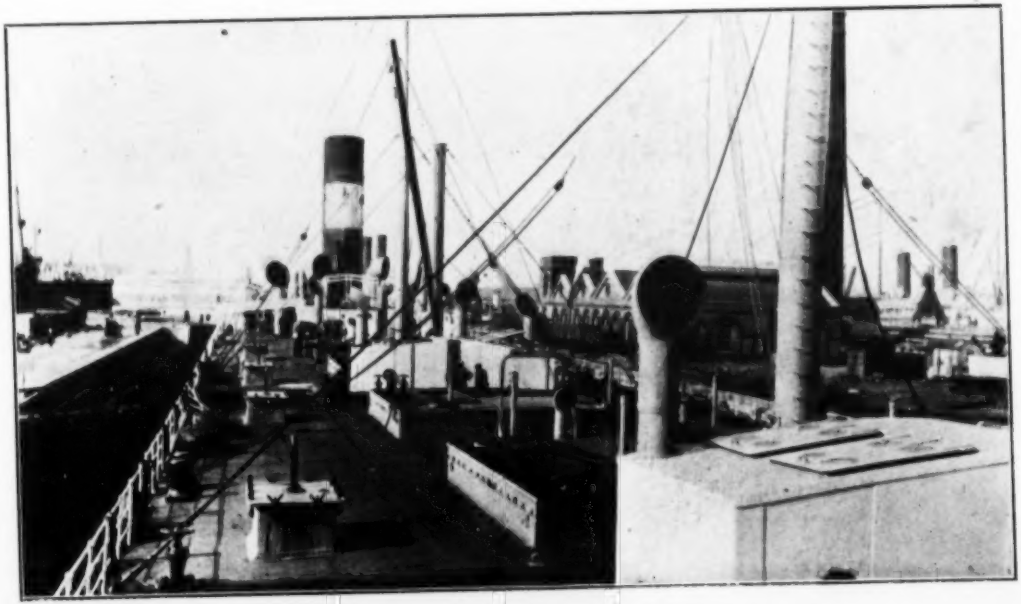


FIG. 52.—S.S. "SAN FRATERNO."

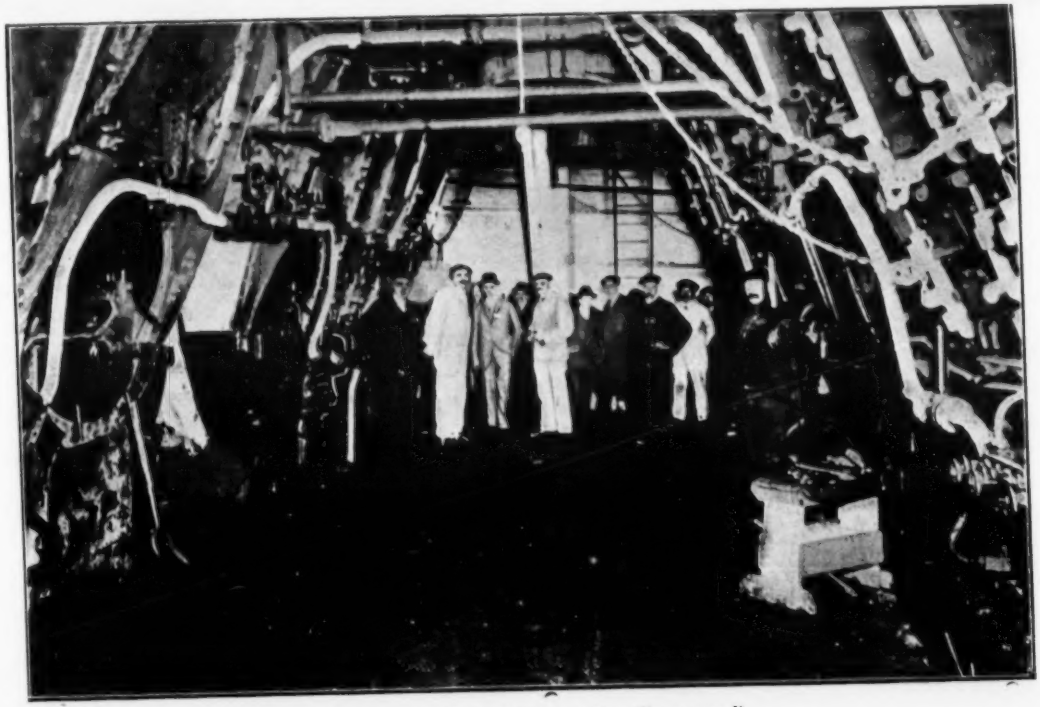


FIG. 53.—Stoke-hold, S.S. "SAN FRATERNO."

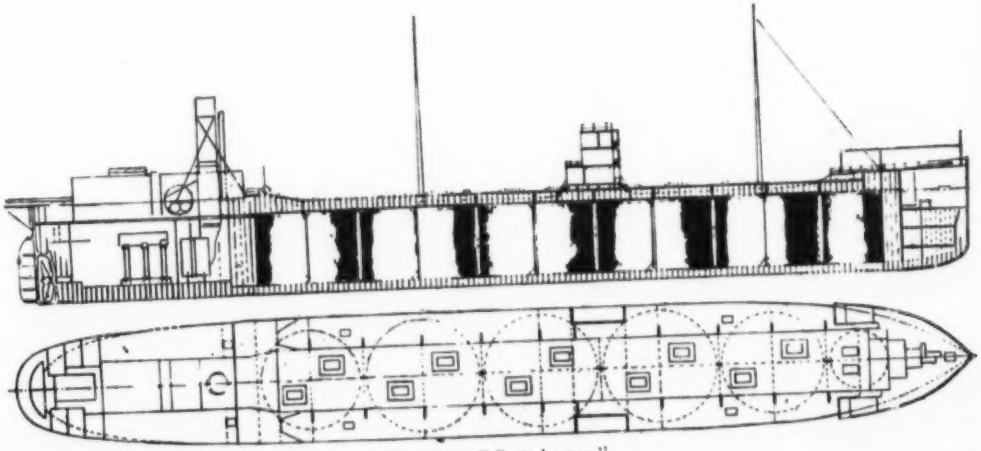


FIG. 54.—S.S. "AZTEC."

FIG. 55.—S.S. "AZTEC."

During the last three years the Eagle Oil Transport Company have built a large fleet including ten vessels, each carrying over 15,000 tons deadweight, and with a total gross tonnage of 145,829.

In 1906 an order was placed by Lord Cowdray for the "San Cristobal," a vessel of 2041 gross tonnage, built on the trunk-principle, there being no spaces alongside the expansion-trunks. The next vessels were the "San Antonio," 5251 gross, built in 1909, and the "San Bernardo," purchased. In 1912 the "San Dunstano" and "San Eduardo" were built, each 6220 tons, and in 1913 the largest order ever placed at one time for tank-steamers was given out, being for ten vessels of 15,000 tons d.w. and seven of 9500 d.w., a total of 216,500 tons deadweight carrying capacity and a gross tonnage of 133,384. The ten 15,000 tonners are now the largest tankers afloat. One of these has since been sold to the French, and one of the smaller ones, the "San Wilfrido," was destroyed by a mine off Cuxhaven a few days before war was declared.

Before dealing with a few points, some of them novel, contained in these vessels, it should be stated that they are all constructed on the Isherwood principle of longitudinal framing, the first oil tank-steamer built on this principle having been the "Paul Paix," in 1908.

The Isherwood design consists of longitudinal frames fitted between transverses instead of the ordinary framing. This arrangement lends itself admirably to the requirement of tank vessels, especially as regards good and distributed attachments to the bulkheads, and there is also a saving in weight of hull over the ordinary system. The accompanying slides show clearly the longitudinal and transverse methods of construction. It may here be mentioned that special care is required in the design and construction of vessels carrying oil in bulk direct to the skin of the ship. The riveting is required to be of a closer pitch than that used in ordinary vessels, absolute fairness of holes and close inspection of workmanship is necessary to ensure oil-tight work. All cargo-tanks and liquid-fuel bunkers must be subjected to severe water-tests before the launching of the vessel; these tests alone generally occupying a period of from four to five weeks.

The ten large vessels are 548 feet in length, 66 feet 6 inches beam, and 41 feet 6 inches in depth, and of the two-deck and shelter-deck type. They are divided into a cross bunker and 12 cargo-tanks by transverse bulkheads, and these are again divided by an oil-tight longitudinal bulkhead, extending the whole length of the trunks, and subdividing the cargo space into 24 compartments. The spaces

alongside the expansion-trunkways can also be utilized for cargo, if required. There is a cofferdam at each end of the cargo space. Two pump-rooms are provided, carried to the bottom of the vessel, which also form cofferdams, and divide the cargo-space into three distinct portions; in all there are 20 bulkheads, and the cargo-tanks have a capacity of about 3,500,000 galls. A double-bottom is fitted under the boilers and a deep tank, forward of cargo-holds, which, together with fore and aft peaks, are utilized for ballasting and trimming the ship.

The liquid-fuel bunkers are arranged in a large cross bunker, immediately forward of the aft cofferdam, and alongside expansion-trunkways with trunks carried up through the shelter-deck, and fitted with screw-down hatches. They will accommodate 4100 tons of oil, and as no fuel or cargo is carried aft of the after cofferdam, the machinery and boiler spaces are entirely cut off from cargo and fuel. Liquid fuel can also be carried, if required, in the forward deep tank. A large pump is fitted forward for dealing with bunker oil. Two of these vessels are also adapted for burning coal, the bunkers being carried under the shelter-deck, and entirely distinct from the oil-fuel spaces.

The whole of the bunker and cargo spaces are fitted with coils of 2-inch piping, through which steam can be passed to deal with heavy viscous oils which require heating before they can be satisfactorily pumped. Each compartment can be heated separately. About 8000 feet of this piping is fitted, providing in the cargo-tanks a square foot of heating surface per 2·7 tons of oil. Special arrangements are made for the testing and filtration of condensed water coming from these coils before it is returned to the boilers, to avoid the possibility of oil entering the latter through a leak in the tubing.

A feature worthy of notice is the pumping installation, which is the largest fitted on any vessels afloat, and by which different classes of oil can be handled in every conceivable manner. It consists of four duplex pumps, two in each pump-room, and each having two 22-inch steam-cylinders and 14-inch oil-cylinders, with a stroke of 18 inches. The capacity of each pump is 300 tons per hour. They are designed to deliver oil against a pressure of 250 lbs. per square inch, and have in practice discharged 15,200 tons of liquid fuel in 31¾ hours through one 14-inch shore line. The main suction-pipes, of which there are two distinct lines, are of 14-inches diameter, with four cross-over suctions in each main tank (48 in all), each provided with a straightway valve, operated by a rod from deck; there are nine discharges on deck with derricks to

trim them for handling hoses. In order to utilize this large pumping power, facilities in the way of pipe-lines leading to storage-tanks ashore have been provided, which illustrates the advances made since the time of the first shore-installations, when one 6-inch line was deemed sufficient.

All the cargo-tanks are provided with large compound hatches, so that in the event of its being required to carry a cargo other than a liquid one, the large hatch cover which carries the smaller oil-tight lid can be removed, thus affording a loading space of 9 ft. × 10 ft. Gas-freeing pipes are also provided to each compartment, being required when carrying spirit cargoes.

A large ventilating fan is fitted in the aft pump-room, which is arranged to draw air from, or discharge it into tanks (when empty) to clear them of gas. The air is drawn or discharged through the main suction-lines, but as the strums are necessarily fitted close to the bottom of the vessel, special air-valves are bolted on the sides of the strums 12 inches from the bottom of the ship, in order to obtain a clear passage for the air in the event of any oil being left in the bottom of the tanks, which might possibly seal the mouth of the strum, or at any rate obstruct the area of the inlet. There are 48 of these air-valves, all operated from the deck.

In addition to the ventilating fan, it is necessary to provide means for introducing steam to tanks for the purpose of assisting in the cleaning and for the expulsion of gas. Steam connections are therefore arranged, so that the tanks can be filled with steam. These connections can also be used as fire extinguishers if required. Redwood gas-detectors are also provided, by means of which the presence of or freedom from gas in the tanks can be ascertained.

The whole of the vessel is of course lighted electrically. All lamps in the pump-rooms are double-globed, and no fuses or switches are fitted there. A wireless apparatus is also installed.

A steam steering-gear of the Wilson Pirrie type, acting directly on the tiller, is fitted aft, with telemotor control from the bridge.

These are the first vessels to be adapted for the burning of what is termed low-flash oil, that is say, oil with a flash-point below 150°, Lloyd's previously not allowing fuel of a lower flash-point to be used. To overcome this difficulty, special arrangements had to be made to satisfy the Classification Committee. It was found necessary to construct a gas-tight isolated chamber adjoining the stokehold, and extending from the bottom of the vessel to the shelter-deck, with entrance only from a house built on this deck. This chamber contains all the pumps, heaters, strainers, etc., for dealing with the supply of liquid-fuel to burners, all in duplicate.

The liquid-fuel pumps for supplying burners are of special design, being simplex, and with long stroke, which has been proved the most satisfactory type for dealing with heavy oils. The steam-cylinders of these pumps are jointed to the bulkhead and project into the stokehold, so that the cylinders, pistons, valves, etc., can be examined, and the stop-valves can be operated from this position without entering the isolated chamber. The oil ends of the pumps, and all rods and glands are kept inside the chamber, in order that no gas can possibly escape to the stokehold. The oil-pipes supplying the burners are jointed to the plating where passing through the bulkhead, and are kept above flooring, and well in sight, in order that, should a leakage occur, it can be immediately detected. A ventilating fan is fitted to this chamber, with the engine in the stokehold, and the driving shaft passing through a packed gland on the bulkhead. A steam-lift is fitted in the chamber to convey attendants to and from deck. The lighting is provided from electric lamps in the stokehold through a heavy glass scuttle. It will therefore be seen that no gas can possibly reach the boiler-fires, and unless any adjustments are required, it is only necessary to enter the chamber in order to clean the filters.

The propelling machinery consists of a set of quadruple-expansion engines with cylinders 28½ in. × 41 in. × 58 in. × 84 in. in diameter, having a stroke of 54 inches. They are supplied with steam by four cylindrical single-ended boilers 16 ft. 3 in. diameter × 12 ft. in length, having four furnaces in each boiler, and working at a pressure of 220 lbs. per square inch, fitted for burning liquid fuel on the Howden Wallsend forced-draught system, in which the oil is heated to a temperature of from 160° to 200° Fahr. (varying with the class of oil used), and then forced through burners at a pressure of about 150 lbs. per square inch; a rotatory motion is imparted to the oil in passing through the burner, before it is discharged through a small orifice to the furnace. Air is supplied to the furnaces by a large fan at a pressure equal to a column of water about 2½ in. in height at the fan, and is heated in the uptake before entering the furnaces. The air is directed by vanes fitted in the furnace fronts, which also impart a rotary motion.

Three boilers are sufficient to maintain full speed at sea, the fourth being used for heating the cargo if required; if this is not necessary, the boilers can be changed over and cleaned, one at a time, at sea, thus avoiding delay in port.

The duties of officers and crew on tank-steamers are specially onerous, and therefore particular attention has been paid to the accommodation.

The captain has been provided with a cabin 10 ft. × 12 ft., a lounge 10 ft. × 7 ft., and a saloon 13 ft. × 10 ft.

Each of the officers and seven engineers has a separate cabin, the chief officer's measuring 8 ft. 6 in. × 10 ft. 6 in., the others 8 ft. 6 in. × 6 ft., the chief engineer's 10 ft. × 13 ft., and the others 8 ft. × 12 ft.

A saloon and separate messrooms for officers and engineers, together with three bathrooms are also fitted. The engineers' accommodation is placed aft under the shelter-deck on the starboard side.

The sailors and firemen are berthed aft under the shelter-deck on the port side, and are provided with separate messrooms, baths, and a room for storage of working clothes. There are also separate cabins for petty officers.

Electric fans are fitted in all cabins, and all doors, scuttles and ventilators are provided with mosquito-proof wire-gauze. A Hall's CO_2 refrigerating machine is fitted in the engine-room, with a chamber to contain meat, vegetables and ice-pails for the use of the crew.

Telephones connect the Marconi house with the captain's cabin and engine-room.

These vessels attained a speed of 12 knots on trial, fully loaded.

Last year an ordinary cargo vessel was fitted for an American firm with cylindrical tanks, placed horizontally in the holds, the idea being that, if required, these could be removed, and the vessel used as an ordinary cargo steamer.

Three vessels of considerable interest were also built last year—the "Aztec," "Brelford" and "Ricardo à Mestres." These were designed with ordinary hulls, having cellular bottoms, but are fitted with cylindrical tanks, standing vertically, and of nearly the same diameter as the beam of the vessel at the particular spot in which they are placed. They are connected with a trunkway on deck, and are attached to the sides of the vessel by webs, so that one-half of the circle of each tank forms a semicircular bulkhead across the vessel, the spaces between the tanks being utilised for accommodation of pumps, valves and pipes.

An oil-tight longitudinal division between the tanks is also provided, and a transverse bulkhead which is not oil-tight, but is required to strengthen the hull, is fitted across each tank internally, and connected to the webs attached to the ship's side.

The expansion-trunkways are also divided transversely at each tank, keeping them distinct.

The top of the cellular bottom forms the bottoms of the cylindrical tanks.

Oil can be carried in the cellular bottom, if required, and also in the spaces, of double concave section in plan, between the circular tanks.

The advantages claimed are:

(1) Easy conversion to ordinary cargo-carrier if required.

(2) No oil-work riveting on the shell of the vessel except on the bottoms in way of cellular bottom, and a portion of the hull if the spaces between tanks are used for cargo.

(3) No stiffening of bulkheads required, as in a flat surface. The stresses on all rivets in tanks are sheer.

(4) Slightly cheaper construction.

(5) Some saving in weight of hull.

(6) Each tank divided by a space from the next one, preventing any possibility of mixing of different classes of oil.

(7) All valves, pipes, etc., outside tanks, and always accessible.

(8) The cellular bottom provides space for water-ballast under ordinary conditions, without using cargo tanks for water.

(9) When cargo requires heating, there is less loss by conduction through hull to sea-water, as there is an air space between the tank sides and the shell plating.

(10) Easier cleaning of tanks when required.

The general design will accommodate a full cargo at about 40 cubic feet to the ton in the cylindrical tanks, and if a lighter cargo is shipped the cellular bottom can be utilized.

The principal objection to the design (and this must be considered a serious one) is the fact that there are a great number of spaces where gas may accumulate, and thus introduce an element of danger. This must be looked upon as a retrograde step, as the first principle of tanker-design has been to do away with all spaces as far as possible, where gas can lie, since it is well known that in some of the earlier vessels accidents occurred through an accumulation of gas in these confined spots. Moreover there does not seem much probability of its being necessary to convert a tanker into an ordinary cargo vessel, now that the use of liquid fuel is becoming more general, and the world's output of petroleum is increasing. Nevertheless it will be interesting to note the performance of these vessels.

A paper dealing with the evolution of the oil-tank steamer would hardly be complete without some allusion to the internal-combustion engine as the propulsive unit.

The Diesel engine is at once suggested to one's mind, and it may be stated that the oil-carrying steamer is for several reasons specially adapted for the use of this type of machine.

The vessel is designed for the carriage of oil.

The bunkers are also in most cases arranged to carry liquid fuel if required.

The total weight of fuel required to be carried is less, thus allowing more cargo to be carried, and also facilitating the arrangements for trim of vessel, if sailing with full cargo and bunkers, and arriving with bunkers practically empty.

The work required by winches is small, though the operation of cargo-pumps must be provided for.

At the present time the most satisfactory and reliable arrangement appears to be that of fitting an oil-fired steam-boiler to deal with windlass and steering-gear, whistle, cooking, warming, etc., at sea, and the working of cargo-pumps in port and at sea. A considerable economy can be obtained by utilizing the heat from the exhaust of the main engine for the generating of steam. Although designs have been put forward and carried out for operating all auxiliary machinery electrically, it must be borne in mind that, in addition to the skilled attention required to maintain it in efficient working order, there is a certain amount of risk involved by the possibilities of shortcircuiting and sparking at motors, especially when carrying spirit cargoes.

The two-cycle Diesel engine offers considerable advantages as regards weight and space occupied, but is attended with certain mechanical difficulties, which up to the present time can hardly be said to have been satisfactorily overcome.

The four-cycle engine, although heavier and occupying more space for equal power, appears to be more reliable.

Bearing in mind these difficulties it may be considered that owners have been wise in not, at the present time, generally adopting the Diesel engine on board tank-steamers, the modern tanker being required to discharge cargo, sign off and sign on crew, and generally discharge ship's duties, and proceed to sea with the utmost dispatch. This allows very little time for overhauling, renewals or repairs, generally necessary with the Diesel engine, and with high freights the whole saving by economy of fuel may easily be lost by detention in port. Under these circumstances the steam-engine is certainly the most reliable up to the present time.

A quadruple reciprocating steam-engine or a geared turbine using liquid fuel and superheated steam may become a formidable rival in point of economy when all running expenses are allowed for, and

may prove a more reliable machine. At the same time, there is little doubt that eventually, when mechanical difficulties have been overcome, the internal-combustion engine in some form will to a great extent displace the steam-operated machine in tank-vessels.

Considering the highly inflammable nature of the cargoes carried in oil-tank steamships, the comparative freedom from loss and damage by fire and explosion is a tribute to the skill and care exercised by those sailing in these vessels, and to the attention given to their construction. The extensive subdivision of these vessels renders them specially seaworthy.

In conclusion I may mention two cases of accident, which have lately occurred, and are of interest.

On the "La Habre," carrying benzine, an explosion took place at sea in the pump-room, and so damaged the bulkheads that spirit from the cargo-tanks entered this space, and became ignited, boiled over on to the decks, set fire also to the liquid fuel in the bunkers, and in a short time the whole vessel amidships was enveloped in flames; fortunately, as will be seen, a high sea was running at the time, and the vessel fell into the trough and shipped a good deal of water, which washed all the burning spirit overboard and away to leeward, leaving the vessel severely damaged, but with no burning spirit on board. She was able to make her way safely to port, having lost about 2,000 tons of benzine.

The "Belridge" was torpedoed by a German submarine, but although severely damaged forward, the bulkheads stood, and the vessel was brought safely into port.

I have, in conclusion, to acknowledge, with thanks, the receipt of photographs and plans from the following gentlemen:—

Messrs. Sir W. G. Armstrong, Whitworth & Co., William Doxford & Sons, Palmer's Shipbuilding and Engineering Co., Smith & Sons, South Shields, and I. W. Isherwood.

DISCUSSION.

The President said it was somewhat surprising that the transport of petroleum in bulk in specially constructed tank steamers should have continued on the Caspian Sea for many years before it was commenced on the Atlantic, although no one had any doubt as to the immense advantages offered by the system initiated by those eminent Swedish pioneers, Messrs. Robert and Ludwig Nobel. He remembered that in those days

many experts were of opinion that, although vessels of that type might be safely navigated on the Caspian, it by no means followed that they would be able to weather the Atlantic storms, and he supposed it was that apprehension which led to the fitting of the earlier vessels employed in the Atlantic trade with a large number of comparatively small tanks.

The extent to which the development of the petroleum industry had been dependent upon the evolution of the bulk system of transport could be readily understood in the light of the particulars the author had given in his paper. It would be quite impossible to supply the present needs of the world in motor spirit, burning oils, lubricating oils, gas oils, and, above all, oil fuel, if it was necessary to revert to the old system of transport, and, by the limited extent to which the demand could be thus met, the cost of the products to the consumer would be greatly enhanced. The fuel-oil trade in particular was essentially a bulk trade, and its rapid and enormous development had undoubtedly been the direct outcome of the evolution of the oil tank-vessel. It was scarcely possible therefore to over-estimate the importance of the subject with which the author had dealt.

It was interesting, in connection with the details which had been given, to note that one of the latest types of oil-carrying ships referred to, in which vertical cylindrical tanks were employed, was a reversion to a very old system of construction. Thirty years ago, in a paper which he read before the Society of Chemical Industry, after a visit to the Russian oilfields, he described some of the oil tank-steamers which he had seen in use on the Caspian Sea as being so constructed that, whilst the fore part of the ship formed a large tank divided into compartments by longitudinal and transverse bulkheads, aft of the engine and boiler space, which occupied the central portion of the vessel, there were two vertical cylindrical tanks of oil, of a diameter of nearly equal to the beam of the ship, and extending slightly above the level of the deck.

He was glad the author had referred to the comparative immunity from accidents due to the inflammable character of the cargoes carried by oil tank-ships. Accidents had occurred, but in a sense they had been beneficial—blessings in disguise, they might be called—because they had disclosed defects which were promptly remedied in vessels of later construction; and having regard to the enormous volume of the trade conducted in oil tank-vessels he thought that designers, and constructors, together with those in charge of the vessels, were alike to be congratulated.

Great care was needed in freeing the tanks from inflammable

vapour when the vessels were to undergo repair, but a method of testing was employed by means of which it was possible to ascertain that the atmosphere of the tanks was in a safe condition before either naked lights or hot rivets were introduced. The test depended upon the discovery, that a tiny non-luminous flame of burning hydrogen is surmounted by a halo or "flame-cap" in air containing far less petroleum vapour than is needed to produce an inflammable mixture.

He had been most favourably impressed with the ability with which the author had contrived to compress within the limits of a paper a comprehensive account of the subject with which he had dealt. He had given an extraordinary amount not only of interesting but of extremely instructive information, and that could not have been done by any man who was not a master of his subject. The author, with characteristic modesty, had refrained from alluding to the part which he had personally taken in the evolution of the oil tank-ship, but it was well-known that he had been associated with that branch of naval architecture for many years, and had been professionally concerned in the construction of some of the latest leviathans, the 15,000 ton tank-steamers, which had been described in the course of the paper.

The Institution was fortunate in having present at the Meeting a distinguished representative of the firm of Armstrongs in the person of Colonel Saxton White, whom he called upon to be good enough to open the discussion on the paper.

Col. Saxton White (Armstrong, Whitworth & Co.) desired in the first place to congratulate the Institution on being the medium for circulating to the world the author's most interesting description of the construction of tank steamers. He did not desire to criticise in any way the information the author had gathered at such very great cost of time and patience, because when the writer of a paper went back for his facts to Chinese history he certainly had more patience than he (Col. Saxton White) was possessed of. The illustration the author had shown on the screen of the Chinese junk proved that there was little, if anything, new under the sun, because the cross section of the Chinese junk shown had a very strong family likeness to the midship section of an ordinary tank steamer, barring the centre line bulkhead.

He was able to confirm most of the interesting information which the author had gathered regarding the early steps taken for the carriage of petroleum in bulk. It was only to be expected that anything the author put forward would be perfectly correct.

He desired, however, to ask the author to modify one paragraph in his paper in which the statement was made, viz. "that the Glückauf was built at the suggestion of Mr. Riedemann of Bremen, by Messrs. Armstrong's, to the designs of the late Col. H. F. Swan." That was, in Parliamentary language, not a correct statement of fact. That ship was, as a matter of history, the successor of a little vessel called the "Armeniak," which his firm built in 1883. The old firm of Charles Mitchell & Co. had for many years built steamers for the ordinary carriage of petroleum in tins or in cases on the Caspian Sea, and in 1883 they built three such vessels for that purpose. One of 210 tons was called the "Massis"; she was built as an ordinary freighter, but with a full midship compartment with a capacity of about 70 tons. The second vessel, called the "Poseidon," was built with McIntyre tanks about 3 ft. 10 in. deep; the oil was carried in bulk within the double bottom, the amount being about 300 tons, the dry cargo being stowed in the holds. Both vessels carried dry cargo as well as fluid. In the same year was completed the "Armeniak," designed in 1882 for the carriage of oil in bulk, to the entire exclusion of dry cargo or case oil; in fact she was the first vessel so constructed of which the firm had any record. She was built with an open bottom; her oil cargo was carried in two tank holds with a centre line division, taking about 500 tons and there was also a smaller hold or large coffer-dam, at each end of the cargo holds, carrying about 108 tons. She had no expansion arrangements or trunks, expansion being dealt with by the hatches themselves, but a small range being required on the Caspian Sea. She had a steam-pump on deck with 6-inch piping, led to each of the four compartments, and from the drawings of that ship she had all the essential features afterwards adopted in the "Glückauf." Mr. Swan (with whom he was associated at the time) and himself were always thinking that what had been done successfully in a small way on the Caspian Sea, could be accomplished with equal success on a larger scale for service on the Atlantic; and the design of the vessel which ultimately became the "Glückauf" was commenced in 1883. Constructional work on her was delayed for some time, but she was a "ship in being" long before Mr. Riedemann appeared upon the scene. The speaker had the pleasure of showing the vessel to Mr. Riedemann, in the "framing" stage of construction, and he therefore thought the credit for the suggestion of the "Glückauf" did not rest with Mr. Riedemann, but with Col. Swan.

There was one clerical error in the paper to which he wished to

direct the author's attention. The author spoke of the "Navahoe" as being a three-masted schooner. As a matter of fact, she had six masts, and he therefore presumed that she should be called a six-masted schooner.

In referring to the "Vaderland," described as the pioneer tank steamer built in this country, the author suggested that the owners were afraid that passenger bookings would be affected if it were known that the ship was carrying petroleum. He thought if any passenger wanted to cross the ocean to-day he could not possibly go in a safer ship than a tank steamer. He thought it would be of interest if he mentioned that the "Beacon Light," whilst making a voyage across the Atlantic, got into trouble with an iceberg; either she ran over the top of the iceberg, or the iceberg turned over and came up under the vessel, knocking in her bottom for about 200 ft. in length. Nevertheless the "Beacon Light" was able to make her way to America, where she was loaded, and brought a cargo of oil across the Atlantic on a very damaged bottom without any loss of cargo. He did not think there were many ships could do that. Recently it took three German mines to sink the "Wilfrido," and, on the other hand, the members unfortunately knew that it had not taken as many mines as that to sink very much larger and more valuable ships, both mercantile and naval. So far from travelling on tank steamers being a disadvantage, from the point of view of safety, to a passenger, he thought he would be well advised to try and get a passage on one of those ships.

There was really nothing to criticise in the paper. He thought the author deserved the thanks of every member of the Institution for the very liberal and broad-minded spirit in which he had dealt with his subject. Many men would have said very much more, but have imparted very much less information. The author had, in his paper, simplified to the expert the construction of tank steamers, because he thought that what the author had not put on record in the paper was not valuable enough to be kept on record in any other form. He had much pleasure in congratulating Mr. Barringer upon his paper, and personally he was very glad to have been present in order to testify in a small way to the genuine work which the author had accomplished in the development and evolution of the tank steamer.

Mr. A. J. Dudgeon said he felt some diffidence in making any remarks upon the most interesting historical paper which the author had so ably composed upon the evolution of the oil tank

ship, but he wished, in the first place, to join with the previous speaker in tendering his thanks to the author for the excellent way in which he had dealt with the subject.

There was one point, however, which he thought had an indirect reference to the different steps by which the present tanker had been evolved, namely, paragraph (4) of the paper which referred to the carriage of oil direct to the skin of the vessel without the use of independent tanks. There could be no doubt that, for sea-going purposes, carriage direct to the skin was the best. He was reminded, in making a few remarks in favour of the adoption of independent tanks in special cases, that when the Anglo-American Oil Company was first started in this country, and it was decided to build a fleet of river and canal barges for the distribution of the oil brought into the River Thames by their steamers, due consideration was given to the two methods of transport. For many reasons independent tanks were adopted, but the principal one which guided the Company and his firm, who were then acting as their consulting engineers, was the danger of collision on a confined river like the Thames, whereby a great quantity of highly dangerous and inflammable oil would have been let loose. At that particular period very considerable difficulty was experienced in obtaining the consent of the Thames Conservancy to the transport of oil in bulk, even in barges. Experience had proved that his firm were right, because for more than twenty years those barges had been worked up and down the river in all conditions of weather; they had been sunk and raised again, but only on two occasions, as far as he could remember, were tanks ever absolutely perforated, and then, on both occasions, only one of the tanks in the barge lost part of its contents. Most of the barges carried from 70 to 90 tons, but there were some carrying from 250 to 300 tons, and each had two independent tanks. Those familiar with the navigation of the River Thames knew what severe work, knocks and collisions barges sustained on the river.

He desired to add a few words on the subject of the internal-combustion engine. He fully agreed with the author that that type of machinery did not at present offer sufficient advantages for its adoption in tank steamers; the author's reasons in that respect were incontestable. As a matter of history he remembered that about ten years ago the Anglo-American Oil Company instructed him to get out a design for a canal tank barge to carry oil in bulk from tankers discharging in the Birkenhead Docks, across the River Mersey for distribution along the canals in and about the Liverpool district. It was decided to try an internal-

combustion engine. He would not mention names, but the engine was made, and after a great deal of testing and many trials on the bench, which were all more or less unsatisfactory, it was finally fitted in the barge and tried in service. He regretted to say it was a total failure, notwithstanding all his efforts and those of many experts to make it go right. He remembered that one particular cause of the breakdown was due to the violent vibration, the cocks and valves, wherever placed about the machinery, not being able to retain their positions for more than a few minutes. It was possible to get the carburettor to work decently well for a short time, but it was suddenly found that too much air was getting in, or the reverse. Anyway, the machinery was removed, and, as was provided for in the original design, a boiler and steam engine were fitted instead, and the barge had ever since been doing her work in a satisfactory manner. With regard to the question of the economy of the modern steam engine, like the author he had a preference for the quadruple expansion engine, but supplied with superheated steam. From the experience gained by his firm in fitting a number of steamers, both triple and quadruple, they were bound to acknowledge that it would take a lot of beating. He desired to ask engineers why their old friend, the reciprocating engine, should not be improved by operating the whole of the moving parts by means of forced lubrication. The turbine system was absolutely dependent upon forced lubrication for a very considerable part of its efficiency. He knew many engineers who contended that the turbine, whether geared or direct, started with an advantage of from 10 per cent. to 15 per cent. over the reciprocating engine from that fact alone. If that was the case, why should not engineers proceed to treat the reciprocating engine in the same way? He desired to mention that, with their quadruple expansion engine boats of about the same power as those referred to by the author, they had a coal consumption, on runs of from 20 to 40 days, down as low as 1·1 lbs. of coal per I.H.P. per hour with north-country coal. By knocking another 10 per cent. off that, either the turbine or the internal-combustion engine would be run very close.

With reference to the question of whether the engines should be placed amidships or aft, he thought it was the experience of most of the gentlemen present that the position in the aft part of the ship was the proper one, from the point of view both of the strength of the vessel and of safety.

He agreed with the author that the building of ships with cylindrical tanks was a retrograde step.

Mr. J. W. Isherwood thought the paper could not fail to be of great interest to the members of the Institution, and that it must have involved considerable labour in its preparation. The author was to be congratulated on a highly successful piece of work.

The idea was pretty generally held that oil had only been carried in bulk during the last thirty or forty years, and it was certainly news to him, and probably to many others, to find that the Chinese junk which was in use about 1700 had, as Col. Saxton White had remarked, a midships section very much like the midships section in use at the present time, and that it was fitted with an expansion-trunk as in the modern steamers.

The paper showed the remarkable progress that had been made in tank vessels during recent years. The "Narragansett," built in 1918, a vessel of 12,000 tons dead weight, for a long time stood alone as the largest oil tanker. That vessel, however, had been a long way eclipsed in size by the 15,000 ton tankers to which the author had referred. They were without doubt the finest tankers afloat, and the author was to be congratulated on his design for those vessels.

One point to which the author did not make direct reference was that the oil tanks were comparatively short, about 22 ft. 6 in. in length, whilst the limit of length provided for by Lloyd's Rules was 28 ft., a figure which was occasionally exceeded. That in his opinion was most important, and the building of the vessels with comparatively short tanks was without doubt a step in the right direction. Experience had undoubtedly shown that, from a structural point of view, the shorter tanks as adopted by the author were much to be preferred.

The author mentioned that those vessels were built on the Isherwood system, and made reference to the fact of there being a good distribution of bracket attachments to the bulkheads. One of the most serious difficulties in tank-ships built on the ordinary transverse system was to keep the bracket attachments to the bulkheads oiltight, as they had in the past caused very considerable trouble, not only from the fact that when different grades of oil were carried there was intermixture, but on account of the cost of upkeep and time lost in effecting structural repairs. The distribution of brackets in the Isherwood system, and the fact that the riveted attachments could be, and were, made of practically the same strength as the girders which they connected to the bulkheads, had overcome one of the annoying problems in tank-ship construction. There were further advantages in

the adoption of the system as compared with the ordinary system. There was a saving in weight of steel in the hull ranging from 10 to 13 per cent., dependent on the size of the vessel, with of course an increase in the dead weight carrying capacity corresponding to the saving in weight of steel. The longitudinal strength was increased from 15 to 20 per cent., which was an important consideration in a tank-ship which could so readily be subjected to bad conditions of loading.

It would have been of very great interest if the author could have referred in some way to the conditions of loading, as he had had great experience of damage caused through bad loading. It was very gratifying to find that the advantages of the Isherwood system had been so fully recognised both by owners and builders, as was demonstrated by the fact that in the last six years no fewer than 143 tank vessels had been arranged to be built on the system, the aggregate registered tonnage exceeding three-quarters of a million tons. The author mentioned that at one time it was considered that in very large tank steamers the machinery should be placed midships, both for structural reasons and for purposes of trim. Experience, however, had shown that, from a structural point of view, there was no objection to the machinery being placed aft, and he thought it might be said that as a general rule it was preferable. With engines midships, however, a captain had more latitude in trimming the vessel, especially so when parts of the cargo were delivered at more than one port. The steamship "Paul Paix," the first vessel built on the Isherwood system, had machinery midships. That for the particular trade of the vessel had answered admirably, and she had been in every way an unqualified success. It was true that an oil ship with engines midships was a more expensive vessel, and the additional expense was probably only justified by the exigencies of any particular trade.

The author was, he thought, right in advocating the building of tank steamers without double bottoms, which were undoubtedly a source of danger. On the American and Canadian Great Lakes there were quite a number of tankers with double bottoms, having been built in that way to save the cargo in the event of the vessels grounding, a not unusual occurrence in shallow waters. A feature of those vessels was that man-holes with flush covers were fitted in the bottom plating, which entirely eliminated the question of ventilation in the double bottom when a vessel was in dry dock for repairs, probably one of the most dangerous periods.

The author mentioned two cases of accident to oil tank steamers,

one of the vessels, the "Belridge," being torpedoed. After that vessel, two other tank-ships had also been torpedoed by the Germans, namely, the "Gulflight" and the "Maricopa," both built on the Isherwood system. In each case the vessels remained afloat, and were safely brought to port, which was a substantiation of the remarks of the author and of Col. Saxton White on the special seaworthiness of tank vessels.

Mr. Barringer, in reply, desired in the first place to thank the members for the very kind way in which they had received his paper, and the various speakers for the very kind remarks they had made in reference to it.

Col. Saxton White had taken exception to one paragraph in the paper referring to the "Glückauf." He did not at all mean to convey that the vessel was designed by Mr. Riedemann, which Col. Saxton White seemed to imply that he did. He had stated in the paper that the steamer was built to the designs of the late Col. Swan, and Col. Swan should receive the whole of the credit for the design, but he understood that Mr. Riedemann suggested that Col. Swan should design the ship.

He was sorry he did not correctly count the masts on the "Navahoe" barge, but he did not count six when there were only three.

Col. Saxton White had also referred to the paragraph in the paper dealing with the "Vaderland," in which it was suggested that the owners were afraid that passenger bookings would be affected if it were known that the ship was carrying petroleum. In those days people did not know how safe a tanker was. Petroleum was then looked upon, like gunpowder, as a most dangerous commodity. It was not a question so much of the seaworthiness of the vessel as of the fact that people were afraid that the cargo would catch fire.

He thanked Col. White for the very nice things he had said about the paper, and he was glad that it seemed to have proved interesting.

He was pleased to find that Mr. Dudgeon agreed with him that it was somewhat of a retrograde step to design a ship with cylindrical tanks and many confined spaces. He was certain that it would be a cause of great anxiety to those who had to repair such a ship in dry dock, especially after it had been carrying a light cargo. The very greatest care would have to be exercised to avoid accident.

Mr. Isherwood suggested that he (the author) should have

dealt with the question of the loading. He could have written a paper on that point alone which would have lasted for two or three evenings. He did not think it was worth while to touch upon it, because he could not have done justice to it in the short time at his disposal. As it was, he had found it exceedingly difficult to condense the paper, and to deal with all the points to which he wished to refer, in such a small compass.

He desired, in conclusion, again to thank the members for their kind reception of the paper, and also to thank the Hon. Secretary and Editor for their assistance in its preparation for press.

The President said the members had already indicated by their applause that it was their desire that he should tender to Mr. Barringer on their behalf a very hearty vote of thanks for the most interesting and instructive paper he had given.

The resolution of thanks was carried by acclamation, and the meeting terminated.

INDEX.

Accidents on tank-ships, 285, 314, 318, 319.
Acetylene, 174.
Accounts, engineering, 68.
Alberta oilfields, 126.
American Petroleum Society, 41.
Amylene, 168.
Aniline, English discovery, 89.
Anthracene, 175.
Anticline, geometry of, 10.
" Armeniak " tank-ship, 317.
Aromatic hydrocarbons, 174.
Articles of Association of the Institution, pt. 1.
" Atlantic " tank-ship, 284.
" Aztec " tank-ship, 303, 305, 311.

" Bakuin " tank-ship, 286.
BARRINGER, W. H., on the Evolution of the Oil Tank-ship, 289, 323.
" Beacon Light " tank-ship, 287, 290.
" Bear Creek " tank-ship, 290.
Benzol, 174.
Bibliography of Trinidad oilfields, 112.
" Black Bear " gas engine, 226.
BOSWORTH, Dr. T. O., on Western Canada oilfields, 139.
British Columbia oilfields, 131.
Bromination of hydrocarbons, 173, 181.
BUCKLE, W., on oils from peat, 85.
Bulkheads in tank-ships, 282, 284, 285, 307.
Burton " cracking " process, 148, 154.
By-Laws of Institution modified, 146.
——, original, pt. 1.

Cable-drilling, 247, 271, 277.
CADMAN, Dr. J. on Trinidad Oilfields, 99, 126.
—— on Western Canada oilfields, 142.
CALDER, W., on Oil-well Engineering, 227, 274.
—— on power in oilfields, 215.
Californian oilfields, 226.
CAMPBELL, J. M., obituary notice, pt. 4, p. xiv.
Canada, Western, oilfields, 126.
CARTER, A., on oilfield equipment, 72.
Casing, thickness of, 265, 273, 275.
Caspian tank-ships, 281, 315.
Catalysis, 158, 175.
Cellulose, 87.
Certificate of Incorporation of the Institution, pt. 1.
" Charles " tank-ship, 284.
" Chemistry of Petroleum " reviewed, pt. 3, p. ix.
Chinese oil-junk, 281, 291, 316, 321.
CHORLTON, H. E. L., Convertible oil or gas engine, 206, 210.
Cofferdam spaces in tank-ships, 282, 285, 289, 308.
Concave-edged bits, 252, 270.
Convertible Oil or Gas Engine, 206, 210.
" Cracking " oils, 147.
CRAIG, E. H. C., on Educational Aims of the Institution, 29.
—— on Trinidad Oilfields, 117.
—— Western Canada Oilfields, 127, 143.
Cylindrical tanks in oil-ships, 311, 315, 320, 323.

DALTON, L. V., obituary notice, 37.
DALTON, W. H., Dips Discontinuous in Depth, 91.
—— Drilling Logs, 191.
—— Educational Functions of the Institution, 95.
David Bridges clutch, 221.
Davies-Calyx drill, 236, 268.
Diamond drill, 235, 268, 275.
Diesel engines on tank-ships, 313.
—— —— on oilfields, 200, 220.
Dips discontinuous in depth, 91.
Dodecane, 172.
Double-bottoms in tank-ships, 282, 286, 312, 317, 322.
Drawings of tools, &c., 231, 264.
Drilling logs defective, 74, 191, 264.
DUCKHAM, A., on " cracking " oils, 182.
——, on Trinidad oilfields, 119.
DUDGEON, A. J., on tank-ships, 318.
DUNN, H. S., on costs of peat drying, 81.

Eagle Oil Transport Co.'s fleet, 295, 297, 299, 301.
EASTLAKE, A. W., on oilfield examination, 71.
Economy, false, 264, 265.
Editorials, 1, 39, 95, 191.
Electricity in oilfields, 199.
" Elizabeth Watts " tank-ship, 283.
" Elsinore " tank-ship, 290, 293

Engines, position in tank-ships, 286, 287, 288, 322.
Equipment of Oil Companies, 47.
Ethane, 173.
Evans, W., obituary notice, pt. 4, p. xvii.
Evolution of Oil Tank-ship, 289.
Expansion-trunks in tank-ships, 281, 282, 285, 286, 311, 317.
Exploratory drilling, 232, 237.

"Fergussons" tank-ship, 285.
Flathead oilfield, B.C., 131.
Flexibility of engine-power, 197, 202, 212, 215, 218, 225.
Flexures discontinuous in depth, 91.
Formulæ, chemical, of hydrocarbons, 172.
——, geometrical, for apparent dip, 25.
——, ——, for pitch of anticline, 26.
——, technical, for thickness of casing, 268.
Free-fall drilling, 259, 272, 276, 279.
Fuel, liquid, in tank-ships, 283, 289, 290, 308, 309.

Gas and Oil Power, on the Institution, 40.
Gas, natural, use on field, 206.
"Glückauf" tank-ship, 285, 317, 323.
Gould, Dr. C. N., on Oil and Gas, Kansas and Oklahoma, 185.
"Gumming" of oil spirit, 161, 176, 179, 180.
Gypsum, drilling in, 275.

Hall, W. A., on Cracking Oils for Motor Spirit, 147, 183.
Hatches, compound, in tank-ships, 283, 289, 309.
Hele-Shaw power-transmission, 222, 226.
Henderson, Dr. J. A. L., on oilfield management, 73.
"Henri Reith" tank-ship, 287.
Heptane and heptylene, 168.
Hexahydrobenzol, 174.
Hexane and hexylene, 173.
Holland, Sir T. H., Some Geometrical Features of the Anticline, 13.
Honorary Membership accepted by Admiral of the Fleet, Lord Fisher of Kilverstone, and by Vice-Admiral Sir Edmond J. W. Slade, 146.
Hydrogenation of Oils, 176.

Inspection of plant, 230, 264.
Institution of Petroleum Technologists, By-Laws modified, 146.
—— Educational Aims and Functions 9, 29, 95.
—— Press notices, 2, 40.
Internal-combustion engines on oilfields, 195.
—— on tank-ships, 313, 319.
Isherwood, J. W., on tank-ships, 321.
Isherwood framing of tank-ships, 307, 321.
Isomerism, 174.
Isoprenes, 180.

Kansas oil and gas fields, 185.
Kimber, E., on delusive oil-shows, 74.
KSX Gas Engine, 206, 208, 209.

"La Habre" tank-ship, 314.
Lake-going tank-ships, American, 322.
Laws and Regulations for oilfields, 55, 72.
Lewes, Prof. V. B., on The Chemistry of the "Cracking" of Heavy Oils, 167.
—— on Petroleum Technology as a Profession, 33.
Library of the Institution, accessions, pt. 2, 2 pp.: pt. 3, p. v: pt. 4, pp. v–xiii.
—— ——, initial suggestions of, pt. 1, p. iii, 40.
Logs, drilling, 74, 191, 264.
Lomax, E. L., on "cracking" oils, 179.
Low-flash oil-fuel on tank-ships, 309.

McCarthy, R. H., on Trinidad oilfields, 122.
McGarvey, W. H., obituary notice, pt. 3, p. vi.
Memorandum of Association of the Institution, pt. 1.
Metacentric displacement in tank-ships, 282, 284, 285.
Methane, 172, 174.
Methylene, 181.
"Mined" tank-ships, 307, 318.
Mining Journal on the Institution, 2.
Mining Magazine on the Institution, 5.
Mosquito danger, 100, 105.
Motor Spirit, "cracked," 147.
Mud-flush, 237, 269.

Naphthalene, 175.
Naphthenes and olefines, 173, 181.
"Narragansett" tank-ship, 287, 321.
"Navahoe" oil-barge, 288, 318, 323.
Newchwang oil-junk, 281, 291.

Obituary notices :—
J. M. Campbell, pt. 4, p. xiv.
L. V. Dalton, 37.
W. Evans, pt. 4, p. xvii.
W. H. MacGarvey pt. 3, p. vi.
Ockenden, M. A., on the "Black Bear" gas-engine, 226.
—— on oil-well engineering, 273.
Oil Companies, Initial Equipment of, 47.
Oil-detection in return water flow, 237, 245, 270.
Oilfields, accounts, 67.
——, Alberta, 126.
——, British Columbia, 131.
——, California, 226.
——, internal-combustion engines in, 195.
——, drilling-systems in Russian, 272.
——, Kansas, 185.
——, Oklahoma, 185.
——, power-systems in Russian, 195.
——, Trinidad, 99, 274.
Oil-pumping gear in tank-ships, 283, 289, 308, 317.
Oil-shale, equipment of works, 62, 63.
Oil shows, delusive surface-, 74.
Oil tank-ship, evolution of, 289.
Oil-well engineering, 227.
—— gas engine, 206, 208.
Oils from peat, 76.
Oklahoma, oil- and gas-fields, 185.
Olefines and naphthenes, 173.
Ormandy, Dr. W. R., on oils from peat, 86.
Oscillation of oil in tank-ships, 282, 284, 285.

Paraffin wax "cracked" to oil, 168.
"Paul Paix" tank-ship, 307, 322.
Peat, oils from, 76.
Pentane, 168.
Pentoses, 87.
Percussion drilling systems, 246.
Perkin, Dr. F. M., on "cracking" oils, 178.
—— on Oils from Peat, 76, 89.
Petroleum-products used in war, 42.
—— -supplies of belligerent countries, 43.
—— -technological training, 31, 229, 263, 272.
Petter, E. W., on oil-engines in oilfields, 217.
Pole-drilling, 256, 271, 279.
"Poseidon" tank-ship, 317.
Power—see Electricity, Internal Combustion and Steam-power.
Power-transmission, 219, 221, 226.
Presidential Address (Sir Boverton Redwood), 9.
Press Notices of the Institution, 2, 5, 40.
Propane, 173.
Pump-rooms in tank-ships, 283, 308.
Pump-valves, &c., 246.
Pumping gear on tank-ships, 283, 289, 308, 317.

Rappoport, F. G., on Internal-Combustion engines on Oil fields, 195, 223.
—— on oilwell engineering, 271.
Reciprocating engines for tank-ships, 320.
Redwood, Sir Boverton, on the aims of the Institution (Presidential Address), 9.
—— on "cracking" oils, 176.
—— on death of Mr. J. M. Campbell, 228.
——, on death of Mr. W. H. MacGarvey, 97.
—— on evolution of oil tank-ship, 314.
—— on initial equipment of Oil Companies, 66.
—— on internal combustion engines on oilfields, 214.
—— on oils from peat, 84.
—— on oil-well engineering, 262.
—— on Trinidad oilfields, 116.
—— on Western Canada oilfields, 138.
Registry of tools, 232.
Review, "Chemistry of Petroleum," by Drs. Tinkler and Challenger, pt. 3, p. ix.
Reynolds, G. B., on oilfield accounts, 67.
Riveting of tank-ships, 307.
Rope-sockets, 254.
Rosenplaenter, C. B., on oilfield legislation, 71.
Rotary drilling, 233, 268, 273.
Russian oilfields, 195, 272.

"San Fraterno" tank-ship, 299, 301.
"San Melito" tank-ship, 297.
"San Wilfrido" tank-ship, 307, 318.
Shot-drill, 236, 268, 275.
Soot in motors, 161, 165.
Speed of drilling, 275, 277.
Stackard, S. F., on English discovery of aniline, 89.
—— on use of megass in oil-burning, 125.
"Stat" tank-ship, 285.
Steam to expel tank-gas, 309.

Steam to extinguish tank fires, 309.
—— to warm oil for pumping, 283, 308.
Steam-power in oil fields, 195, 213.
Suez Canal, tank-ships in, 288.
Sugar-cane refuse in oil-burning, 125.
"Sviet" tank-ship, 286.

Tanks, length of, in ships, 321.
——, separate from skin of ship, 282, 284–286, 311, 315, 320, 323.
Tank-ship, evolution of, 279.
Terpenes in "cracked" spirit, 161, 176, 179, 180.
Thames, oil-barges on the, 319.
THOMPSON, A. B., on Trinidad oil-fields, 123.
Toluene, 175.
Toluol, 174.
Tool-joints, 254, 270, 279.
Tools, bad metal for, 264, 274.
——, drawings of, 231, 264.
——, inspection of, 231, 264.
——, registry of, 232.
Torpedoed tank-ships, 314, 323.
Towage of tank-barges, 288.
Training, technological, 31, 229, 263, 272.
Trinidad oilfields, 99, 274.
—— —— bibliography, 112.

Underreaming, 253, 259.

"Vaderland" tank-ship, 284, 318, 323.
Vancouver oilfields, prospective, 137.
Vapour-test in tanks, 309, 316.
Ventilation of tanks, 283, 309.

War, petroleum products used in modern, 42.
——, petroleum supplies of belligerents in, 43.
——, services of Institution offered in, 39.
Wash-plates, bulkheads serve as, 282, 284, 285.
Water, depth in drilling, 251, 278.
Well-engineering, 227.
WELLS, J., on Equipment of Oil Companies, 47, 75.
—— on oil-well engineering, 263.
—— on power in oilfields, 220.
WHITE, Col. SAXTON, on evolution of tank-ships, 316.
Wire-rope, duration of, 250, 270.
WYATT, H., on Petroleum Products in War, 42.
—— on Petroleum Supplies of Belligerents, 43.
—— on power in oilfields, 219.
—— on Trinidad oilfields, 123.

Xylol, 174.

"Zoroaster" first oil tank-steamer, 281.

CROWTHER & GOODMAN, Printers, 124, Fenchurch Street, London, E.C.